VOL. XXXVII OCTOBER 1953 NO. 4

THE JOURNAL OF AGRICULTURE

of the

UNIVERSITY OF PUERTO RICO

THE DEVELOPMENT OF A MATHEMATICAL CONCEPT TO INTERPRET THE RELATION BETWEEN PLANT COMPOSITION AND CROP YIELD ..... *Bernardo G. Capó and George Samuels* 249

IRON CHLOROSIS ON DRACAENA SANDERIANA
George Samuels and Héctor R. Cibes 265

POTASSIUM COMPETITION IN A KUDZU-MERKER GRASS ASSOCIATION ..... *George Samuels and Pablo Landrau, Jr.* 273

RESULTS OF TESTS WITH NEW FUNGICIDES FOR THE CONTROL OF DAMPING-OFF OF TOBACCO IN PUERTO RICO
L. A. Alvarez-García and Lidy López-Matos 283

FUNGICIDAL CONTROL OF EARLY AND LATE BLIGHT OF THE POTATO IN PUERTO RICO
L. A. Alvarez-García, J. Adsuar, J. P. Rodríguez, A. Cruz-Miret, F. Aróstegui, R. Olivencia, and F. Rochet 288

PUBLISHED BY
UNIVERSITY OF PUERTO RICO
AGRICULTURAL EXPERIMENT STATION
RÍO PIEDRAS, P. R.
Issued, October, 1953.

Entered as second-class matter June 1, 1953, at the post office at Río Piedras, under the Act of August 24, 1912, as amended by the Act of August 4, 1947.

AGRICULTURAL EXPERIMENT STATION

University of Puerto Rico, JAIME BENÍTEZ, M.A., LL.M., *Chancellor*

Station Staff[1]

Arturo Roque, M.S. ..... *Director*
E. G. Capó, Ph.D. ..... *Assoc. Dir. for Research*

Agricultural Economics and Rural Sociology
P. B. Vásquez-Calcerrada, Ph.D., Rural Sociol., Head of Dept.
H. Bayrón, B.S., Asst. Economist
A. Burgos, M.S., Res. Asst. in Rural Sociol.
J. R. Calderón, B.S., Res. Asst. in Econ.
G. Espinet, B.S., Res. Asst. in Econ.
D. Haddock, M.B.A., Econ.
L. Hernández[2], B.A., Res. Asst. in Econ.
P. Negrón, B.S., Res. Asst. in Econ.
J. Oliviéri[2], B.S., Res. Asst. in Econ.
M. Piñero, B.S., Assoc. Econ.
J. M. Ríos, M.S., Asst. Econ.
G. Rivera-Hernández, M.S., Res. Asst. in Econ.
F. Román, M.S., Asst. Econ.
E. Silva, M.S., Asst. Econ.
C. Stella, B.S., Res. Asst. in Econ.

Agronomy and Horticulture
E. G. Capó, Ph.D. Head of Dept.
L. Alemañy, B.S., Res. Asst. in Hort.
S. Alers, B.S., Res. Asst. in Agron.
F. Arósteguí, M.S., Assoc. Agron.
I. Bangdiwala, M.S., Asst. Statistician
A. Cruz-Miret, B.S., Res. Asst. in Agron.
P. Lazcano, Jr., M.S., Asst. Agron.
F. Méndez, M.S., Agron.
W. Pennock, M.S., Hort.
J. P. Rodrigues, B.S., Assoc. Agron.
V. M. Valle, M.S., Asst. Agron.

Animal Husbandry
L. Rivera-Brenes, Ph.D., An. Husb., Head of Dept.
J.I. Cabrera, M.S., Asst. An. Husb.
H. Ciordia, Ph.D., Assoc. Parasit.
E. N. Colón, B.S., Res. Asst. in An. Husb.
L. F. Colón, B.S., Res. Asst. in Chem
F. J. Marxhán M.S., Asst. Chem
J. Rivera-Anaya, D.V.M. Assoc. Vet.
A. Torresh, M.S., Res. Asst. in Bact.

Central Analytical Laboratory
A. Riera, B.S., Assoc. Chem. in Charge
N. Flores, B.S., Anal. Chem.
L. Igaravidez, B.S., Asst Chem.
M Medina de Mariani, M.S., Anal. Chem. (Mrs.)
M. T. Torres[4], B.S., Anal. Chem. (Miss)
G. Viscarra, B.S., Anal. Chem.

Chemistry
F. Sánchez-Nieves, M.S., Chem., Head of Dept.
J. Escabí, B.S., Analytical Chem. (Miss)
I. G. Riesenkoff, M.S., Asst. Chem. (Mrs.)
A. Rodrigues, B.S., Asst. Chem.
R. Santini, Ph.D., Assoc. Chem.

Entomology
G. N. Wolcott[4], Ph.D., Ent. Head of Dept.
P. Malaret, B.S., Res. Asst. in Ent.
L. F. Martorell, Ph.D., Ent. Actg. Head of Dept.
J. L. Moreno, B.S., Res. Asst. in Ent.
M. E. Pérez, M.S., Asst. Ent.

Plant Breeding
P. González-Ríos, M.S., Plant Breeder, Head of Dept.
E. Bonetta, M.S., Asst. Plant Breeder
A. Hernández, M.S., Res. Asst. in Cytology (Mrs.)
F. Mariota-Trías, M.S., Asst. Plant Breeder
C. Moscoso, M.S., Res. Asst. in Plant Breeding
J. Muratti, M.S., Asst. Geneticist
R. Olivencia, M.S., Asst. Plant Breeder
J. Vélez-Fortuño, M.S., Asst. Plant Breeder

Plant Pathology
L. A. Alvarez, M.S., Plant Path., Head of Dept.
J. Adsuar, B.S., Plant Path.
J. Bird, M.S., Asst. Plant Path.
L. López[2], B.S., Res. Asst. in Plant Path.
J. Pérez, Ph.D., Assoc. Bact.
G. W. Brushl[2], Ph.D., Path. in Cane Breeding

Plant Physiology
———, Plant Physiol., Head of Dept.
H. Cibes, Ph.D., Assoc. Plant Physiol.
M. C. Fernández, Ph.G., Asst. Plant Physiol. (Mrs).
E. Hernández[3], M.S., Asst. Plant Physiol.
L. Miranda[4], B.Sc., Res. Asst. in Chem. (Miss)
G. Samuels, Ph.D., Plant Physiol.
E. A. Tió, Ph.D., Assoc. Plant Physiol.

Soils
J. A. Bonnet, Ph.D., Soil Sci., Head of Dept.
M. A. Lugo-López, Ph.D., Assoc. Soil Sci.
M. Martínez, M.S., Res. Asst. in Agr. Eng.
J. Roldán, B.S., Asst. Chem.

Cooperative BPISAE Research Project
J. Vicente Chandler[4], M.S., Supv. B.P.I.S. & A.E.
F. Abruña[3], M.S., Soil Sci.
J. Figarella[3], B.S., Soil Sci.
R. Caro-Costa[3], B.S., Agron.
S. Silva[3], Soil Sci. Aid

School of Tropical Medicine
D. Fernández, B.S., Asst. in Nutrition (Miss)
A. Muñiz, B.S., Res. Asst. in Nutrition (Miss)

College of Agriculture
R. U. Blasingame, B.S., Visiting Agric. Eng.

Library
Joan P. Hayes, M.A., (Miss), Librarian

Office of the Editor
R. Molinary-Saldo, B.S., Assoc. Ed.
T. Swann Harding, B.S., English Tech. Ed.

Service Department
M. Guevara, M.S., Adm. Asst.
C. Rivera-López, B.S., Asst. Agron. in Charge Sta. Farm

Rum Pilot
V. Rodríguez-Benítez, M.S., Technical Director
H. M. Brau, M.S., Chem. Eng.
A. García, Ph.D., Assoc. Chem.
Y. P. de Landrau, M.S., Asst. Chem. (Mrs.)
R. Mariñelarena, Ph.D. Assoc. Bact.
J. Rivera, M.S., Asst. Chem. (Miss)
B. Camacho, B.S., Res. Asst. in Chem. (Miss)
J. Rosso, B.S., Res. Asst. in Chem. (Miss)

Substations and Seed Farms:
Plant Propagation, Trujillo
W.Pennock, M.S., Hort. in Charge
Main Office—Seed Farms Division
A. Amy, B.S., Act. Chief
C. Rigau, B.S., Res. Asst. in Agron.
Castañer Substation (Coffee)
A. Rodrigues-Cabrera, M.S., Asst. Agron. in Charge
S. Rodrigues[3], B.S., Res. Asst. in Agron.
J. Toro, B.S., Res. Asst. in Hort.
Isabela Substation
A. Riollano, M.S., Agron. in Charge
M. Avilés, M.S., Assoc. Agron. in Charge Seed Farm
R. Abrams, B.S., Res. Asst. in Agron.
R. Gandía-Caro, B.S., Res. Asst. in Agron.
R. García-Lugo, B.S., Res. Asst. in Hort.
L. B. Ortiz, M.S., Res. Asst. in Agron.
Lajas Substation
A. González-Chapel, M.S., Assoc. An. Husb. in Charge
I. Carlo, Res. B.S., Asst. in An. Husb.
F. Gelpí, B.S., Res. Asst. in An. Husb.
L. Meyer, B.S., Res. Asst. in Agron.
C. A. Ortiz-Lugo, B.S., Asst. Agron.
J. Ortiz-Vélez, B.S., Res. Asst. in An. Husb.
M. Rojas, M.S., Asst. An. Husb.
R. Vásquez, B.S., Res. Asst. in Agron.
Corozal Substation (Minor Crops)
H. Gandía-Díaz, B.S., Assoc. Agron. in Charge
Tobacco Substation
A. S. Amy, B.S., Assoc. Agron. in Charge
M. Manzano, B.S., Asst. Biochem.
A. Meléndez-González, B.S., Assoc. Agron.

---

[1] Date of issue, July 1, 1962.
[2] Leave to pursue studies.
[3] U.S.D.A. collaborators.
[4] Other leaves.

THE JOURNAL OF AGRICULTURE
OF THE UNIVERSITY OF PUERTO RICO

Issued quarterly by the Agricultural Experiment Station of the University of Puerto Rico, for the publication of articles by members of its personnel, or others, dealing with any of the more technical aspects of scientific agriculture in Puerto Rico or the Caribbean Area.

Vol. XXXVII October, 1953 No. 4

THE DEVELOPMENT OF A MATHEMATICAL CONCEPT TO INTERPRET THE RELATION BETWEEN PLANT COMPOSITION AND CROP YIELD

Bernardo G. Capó and George Samuels[1]

INTRODUCTION

The hypothesis that a relationship exists between the composition of a plant and its yield is a valid one which has gained acceptance in the world of science. The mechanism and values of this relationship have been proposed and discussed by such workers as Borden (1–3)[2], Clements (6), Innes (8), Macy (11), Mitchell and Chandler (12), Thomas (14), Tyner (15), and Ulrich (16). However, the expression of this relationship in mathematical form is not readily accomplished.

Borden, working with sugarcane in Hawaii (1–3), made use of certain critical values for the percentage of major nutrients in the leaf and cane at various sampling periods that were associated with optimum yields, but he did not designate any specific mathematical relationship between plant composition and yield. Clements (6), also working with sugarcane in Hawaii, designated the "primary index" or percentage of total sugars in leaf sheaths as a criterion of when to fertilize. Innes (8), in Jamaica, found a linear relation between the relative increases in percentage of nutrients in the leaves, on a dry-matter basis, and the relative response in yield. The general equation determined was that the relative response in yield equalled a constant times the relative increase in percentage of leaf nutrient, on a *dry-matter* basis—plus another constant.

Macy (12), using the concept of a critical content of a nutrient by a plant, above which luxury consumption and below which poverty adjustment were assumed, presented no definite mathematical relationship between plant yield and composition. Thomas (14) developed the concept of foliar diagnosis for following the "course of nutrition" as reflected by "intensity" and "quality". He, however, made no attempt to evolve this concept into a mathematical form. Tyner (15) obtained a highly significant

[1] Associate Director for Research, and Plant Physiologist, respectively, Agricultural Experiment Station, University of Puerto Rico, Río Piedras, P. R.

[2] Numbers in parentheses refer to Literature Cited, pp. 263–4.

correlation for a linear relation between yield and nutrient content of the leaves of corn. Ulrich (16) expressed the general relationship of plant-nutrient composition in a form similar to Jenny's (9) equation for the factors affecting soil formation. In an equation for plant nutrients, Ulrich stated that the concentration of a given nutrient X would be a function of the soil S, climate Cl, time T, plant P, management M, and possibly others. This relationship was expressed in the following generalized equation:

$$X = f\ (S,\ Cl,\ T,\ P,\ M,\ \cdots).$$

Ulrich did not offer any specific equation for relating the yield of the plant to its composition.

It is the purpose of this paper to suggest a mathematical relationship as an approximation to the quantitative relationship existing between the composition of a plant and its yield as determined for hegari sorghum in the greenhouse under varying climatic and soil conditions, and fertilizer levels.

EXPERIMENTAL PROCEDURE

The data to test the relationship between plant composition and yield were obtained from pot tests performed by Capó (4) to determine the available nutrient contents of Puerto Rican soils. The details of the greenhouse technique and procedure have been described in a previous publication (5).

For the purposes of this study the harvested hegari sorghum plants used in some of the experiments were analyzed for nitrogen, phosphorus, and potassium. A total of 78 pairs of corresponding values for nitrogen, 73 for phosphorus, and 43 for potassium were utilized; all treatments were replicated from two to four times. The experiments used in this study were conducted on samples of 28 different soil series. The levels of nitrogen, phosphorus, and potassium used, together with the soil-to-sand dilutions, are given in table 1. The mean yields of sorghum and its content of nitrogen, phosphorus, and potassium, are also given in table 1. The experiments were so designed that when any one fertilizer element was varied, (nitrogen, phosphorus, or potassium), the remaining two elements were supplied in quantities sufficient to meet all nutrient demands, so as not to be limiting. For each nutrient studied there existed three levels of the nutrient: none, one unit, and two units (see table 1).

ARC TANGENT AND PLANT YIELDS

As the soil pot tests used for the experimental data were conducted using various soils with different soil-to-sand dilutions, and were carried out in different seasons of the year, the comparison of yields from different experiments was invalid on a direct basis. However, the various experiments

TABLE 1.—*The results of Mitscherlich pot tests involving nitrogen, phosphorus, and potassium on the soils of Puerto Rico with hegari sorghum as the indicator crop*

Experiment No.	Soil[1]	Fertilizer units[2]	Mean yield of dry matter per pot	Relative yield (Yr)	Nutrient content of plant in dry weight	Arc tangent of nutrient content (X)
		A: *Nitrogen*				
			Grams		*Percent*	
35	Cialitos clay	0	8.45	20.4	0.48	25.6
		1	42.35	102.4	.81	39.0
		2	41.35	100.0	1.49	56.2
36	Coloso silt loam	0	12.15	27.4	.55	28.8
		1	33.10	74.6	.79	38.3
		2	44.35	100.0	1.26	51.9
37	Catalina clay (level phase)	0	14.40	37.5	.61	31.4
		1	33.55	87.3	.94	43.2
		2	38.45	100.0	1.64	58.6
38	Vega Alta sandy loam	1	31.05	98.7	1.15	49.0
		2	31.45	100.0	1.82	61.2
39	Múcara silty clay loam	1	37.20	82.9	.81	39.0
		2	44.85	100.0	1.41	54.6
40	Ciales clay loam	1	38.90	106.4	.92	42.6
		2	36.55	100.0	1.50	56.3
41	Tiburones muck	1	15.80	74.4	1.73	60.0
		2	21.55	100.0	1.73	60.0
42	Los Guineos clay	0	19.10	40.9	.62	31.8
		1	36.50	78.1	1.03	45.9
		2	46.75	100.0	1.48	56.0
43	Toa silty clay loam	0	4.70	13.0	.67	33.8
		1	27.40	75.8	.61	31.4
		2	36.15	100.0	1.18	49.7
44	Nipe clay	0	5.20	51.2	.61	31.4
		1	19.20	189.2	1.13	48.5
		2	10.15	100.0	1.98	63.2
45	Coloso clay	0	8.85	20.9	.62	31.8
		1	34.35	81.2	.78	38.0
		2	42.30	100.0	1.29	52.2
46	Cabo Rojo clay	0	6.60	24.9	.63	32.2
		1	18.00	67.8	1.17	49.5
		2	26.55	100.0	1.74	60.1
47	Mabí clay	0	14.90	32.1	.46	24.7
		1	52.25	112.7	.68	34.2
		2	46.35	100.0	1.20	50.1
48	Múcara silt loam	0	19.15	30.9	.59	30.5
		1	47.15	76.2	.56	29.2
		2	61.90	100.0	.65	33.0
64	Aguilita stony clay	0	10.55	62.1	.75	36.9
		1	15.55	91.5	1.13	48.5
		2	17.00	100.0	1.52	56.7

TABLE 1.—*Continued*

Experiment No.	Soil[1]	Fertilizer units[2]	Mean yield of dry matter per pot	Relative yield (*Yr*)	Nutrient content of plant in dry weight	Arc tangent of nutrient content (*X*)
		A: *Nitrogen—Continued*				
			Grams		*Percent*	
65	Ponceña clay	0	9.20	48.2	0.81	39.0
		1	17.40	91.1	1.12	48.2
		2	19.10	100.0	2.21	65.6
66	Amelia clay	0	3.00	23.2	1.30	48.5
		1	9.70	74.9	1.33	53.1
		2	12.95	100.0	1.52	56.7
67	Guánica clay	0	16.65	100.6	1.21	50.4
		1	18.45	111.5	1.47	55.8
		2	16.75	100.0	1.49	56.1
68	Fraternidad clay	0	7.65	46.8	.86	40.7
		1	11.30	69.1	1.05	46.4
		2	16.70	100.0	1.49	56.1
69	Mercedita clay	0	7.55	32.3	.68	34.2
		1	13.50	57.7	.86	40.7
		2	21.60	100.0	1.05	46.4
76	Moca clay	0	7.80	98.4	3.28	73.0
		2	7.93	100.0	2.85	70.7
77	Colinas clay	0	4.87	45.6	1.02	45.6
		2	13.50	100.0	2.09	64.4
78	Vega Baja silty clay	0	7.88	53.1	.64	32.6
		1	11.40	76.8	.89	41.7
		2	14.85	100.0	1.59	57.8
80	Aguirre clay	0	7.05	44.6	.62	31.8
		1	10.85	68.7	.82	39.4
		2	15.80	100.0	1.21	50.4
81	Vayas clay	0	8.40	34.9	.62	31.8
		1	17.45	72.6	.86	40.7
		2	24.05	100.0	1.25	51.3
82	Mabí clay	0	10.75	55.6	.74	36.5
		1	18.15	93.8	.86	40.7
		2	19.35	100.0	1.30	52.5
83	Aguirre clay	0	5.40	39.9	.68	34.2
		1	13.40	98.9	.58	30.1
		2	13.55	100.0	.98	44.4
88	Fajardo clay	0	9.98	70.3	1.54	57.0
		1	13.48	94.9	1.89	62.1
		2	14.20	100.0	2.16	65.2
		B: *Phosphorus*				
35	Cialitos clay	1	26.60	64.3	0.27	15.1
		2	41.35	100.0	.39	21.1

TABLE 1.—*Continued*

Experiment No.	Soil[1]	Fertilizer units[2]	Mean yield of dry matter per pot	Relative yield (Y_r)	Nutrient content of plant in dry weight	Arc tangent of nutrient content (X)
	B: *Phosphorus—Continued*					
			Grams		*Percent*	
36	Coloso silt loam	0	15.80	35.6	0.42	22.8
		1	40.65	91.7	.51	27.0
		2	44.35	100.0	.33	18.4
37	Catalina clay (level phase)	1	26.95	70.1	.41	22.3
		2	38.45	100.0	.39	21.1
38	Vega Alta sandy loam	0	1.95	6.2	.16	9.1
		1	30.20	96.0	.28	15.6
		2	31.45	100.0	.37	20.3
39	Múcara silty clay loam	0	2.80	6.2	.18	10.2
		1	32.45	72.4	.28	15.6
		2	44.85	100.0	.30	16.7
40	Ciales clay loam	0	14.40	21.8	.35	10.2
		1	38.90	86.8	.30	17.7
		2	36.55	100.0	.49	26.1
41	Tiburones muck	1	22.15	104.0	.43	23.3
		2	21.25	100.0	.60	31.0
42	Los Guineos clay	1	36.50	78.1	.14	8.0
		2	46.75	100.0	.24	13.5
43	Toa silty clay loam	1	27.40	75.8	.32	16.7
		2	36.15	100.0	.31	17.2
45	Coloso clay	1	34.25	81.2	.28	16.7
		2	42.30	100.0	.34	18.7
46	Cabo Rojo clay	1	18.00	67.8	.27	16.2
		2	26.55	100.0	.30	16.7
47	Mabí clay	1	52.25	112.7	.25	14.0
		2	46.35	100.0	.25	14.1
48	Múcara silt loam	0	24.80	39.0	.27	14.0
		1	58.55	92.0	.26	15.1
		2	63.65	100.0	.26	20.3
64	Aguilita stony clay	0	8.30	61.3	.31	14.6
		1	12.75	94.1	.38	17.2
		2	13.55	100.0	.43	23.3
65	Ponceña clay	0	18.85	118.6	.70	35.0
		1	21.55	135.5	.64	32.6
		2	15.90	100.0	.67	33.7
66	Amelia clay	0	3.90	29.9	.25	14.0
		1	9.25	70.9	.47	25.2
		2	13.05	100.0	.52	27.4
67	Guánica clay	0	17.50	105.7	.47	25.2
		1	20.35	123.0	.59	30.5
		2	16.75	100.0	.70	35.0

TABLE 1.—*Continued*

Experiment No.	Soil[1]	Fertilizer units[2]	Mean yield of dry matter per pot	Relative yield (Yr)	Nutrient content of plant in dry weight	Arc tangent of nutrient content (X)
		B: *Phosphorus—Continued*				
			Grams		*Percent*	
68	Fraternidad clay	0	14.25	87.2	0.50	26.6
		1	15.05	92.0	.55	28.8
		2	16.70	100.0	.59	30.6
69	Mercedita clay	0	16.55	70.7	.36	19.8
		1	23.05	98.5	.49	26.1
		2	23.60	100.0	.51	27.1
76	Moca clay	0	2.40	25.6	.38	20.8
		2	9.37	100.0	.34	18.7
77	Colinas clay	0	3.93	28.1	.15	8.5
		2	14.00	100.0	.50	26.6
78	Vega Baja silty clay	0	7.87	52.7	.52	27.5
		1	11.90	80.1	.40	21.8
		2	14.85	100.0	.42	22.8
80	Aguirre clay	0	17.10	108.3	.30	16.7
		1	17.05	107.9	.33	18.3
		2	15.80	100.0	.47	25.2
81	Vayas clay	0	20.00	83.2	.48	25.6
		1	17.40	72.3	.77	37.6
		2	24.05	100.0	1.07	47.0
82	Mabí clay	0	18.55	95.9	.67	33.8
		1	19.50	100.8	.86	40.7
		2	19.35	100.0	.89	41.7
83	Aguirre clay	0	11.55	85.2	.41	22.3
		1	14.70	108.5	.35	19.3
		2	13.55	100.0	.51	27.1
88	Fajardo clay	0	8.02	62.6	.37	20.3
		2	12.82	100.0	.42	22.8
V	Vega Baja silty clay	0	12.90	76.1	.10	5.7
		1	14.38	84.8	.29	16.2
		2	16.95	100.0	.29	16.1
		C: *Potassium*				
48	Múcara silt loam	0	62.95	96.3	0.95	43.5
		1	53.30	81.6	1.61	58.2
		2	65.35	100.0	1.60	58.0
64	Aguilita stony clay	0	12.05	82.3	2.12	64.7
		1	18.85	128.7	2.54	68.5
		2	14.65	100.0	2.18	64.5
65	Ponceña clay	0	23.35	102.6	1.66	58.9
		1	21.10	92.7	2.31	66.6
		2	22.75	100.0	2.14	64.9

TABLE 1.—*Continued*

Experiment No.	Soil[1]	Fertilizer units[2]	Mean yield of dry matter per pot	Relative yield (*Yr*)	Nutrient content of plant in dry weight	Arc tangent of nutrient content (*X*)
		C: *Potassium—Continued*				
			Grams		*Percent*	
66	Amelia clay	0	6.90	54.5	1.10	47.7
		1	8.85	70.0	1.74	60.1
		2	12.65	100.0	2.04	63.9
67	Guánica clay	0	21.00	120.7	3.08	72.0
		1	17.35	99.7	3.30	73.1
		2	17.40	100.0	3.10	72.1
68	Fraternidad clay	0	13.40	77.5	1.67	59.1
		1	13.75	79.5	2.40	67.4
		2	17.30	100.0	2.52	68.4
69	Mercedita clay	0	17.65	81.9	2.51	68.3
		1	20.05	93.0	2.55	68.6
		2	21.55	100.0	2.95	71.3
76	Moca clay	0	9.00	95.7	1.86	61.7
		2	9.40	100.0	2.06	64.1
77	Colinas clay	0	11.03	72.4	1.86	47.5
		2	15.23	100.0	2.06	64.1
78	Vega Baja silty clay	0	12.45	83.8	1.69	59.4
		1	14.28	96.2	1.20	50.2
		2	14.85	100.0	1.25	51.4
80	Aguirre clay	0	11.05	70.0	1.25	51.3
		1	17.70	112.1	1.71	59.7
		2	15.80	100.0	1.80	60.9
81	Vayas clay	0	16.95	70.5	1.38	54.1
		1	19.85	82.5	1.79	60.8
		2	24.03	100.0	2.03	63.8
82	Mabí clay	0	17.50	90.4	1.17	49.5
		1	18.25	94.3	1.76	60.4
		2	19.35	100.0	2.58	68.8
83	Aguirre clay	0	10.20	75.3	1.62	58.3
		1	15.50	114.8	1.66	58.9
		2	13.35	100.0	1.79	60.8
88	Fajardo clay	0	13.58	91.6	1.28	52.0
		1	14.48	97.7	1.92	62.5
		2	14.82	100.0	2.20	65.5

[1] Soil: sand mixture was 1:2 for all experiments with nitrogen; for phosphorus 1:2 for experiments 35–47, 67–69, 78–83, and V; 1:1 for experiments 48, 64–66, 76, 77, and 88; for potassium 1:2 for experiments 78–83; 1:5 for experiments 48, 64–66, and 88; and 1:6 for experiments 67–77.

[2] Fertilizer units: 1N = 0.5 gm. NH_3 per pot, 1P = 0.5 gm. P_2O_5 per pot, and 1K = 0.5 gm. K_2O per pot for experiments 35, 47, 76, 77; 1N = 0.3 gm. NH_3 per pot, 1P = 0.3 gm. per pot, and 1K = 0.3 gm. K_2O per pot for experiments 48, 64–69, 78–88. When one fertilizer element was varied, the other two were kept at the highest (2 fertilizer units) level.

could be compared by means of "relative yields". The relative yield was defined for this purpose as the percentage which the actual yield of a crop was of the yield obtained with the heaviest application of the given nutrient made to the growth medium.

The relative yield for the series of experiments was determined by use of the formula:

$$Yr = \frac{Ya}{Yn} \times 100, \qquad 1$$

where Ya is the yield of the treatment in which there is zero or increasing increments of a given fertilizer element, Yn is the yield of the treatment in which the given fertilizer element is applied in maximum quantity, and Yr is the relative yield. The relative yields of the pot tests are given in table 1, by treatments.

To evaluate the relationship between the nutrient composition of the sorghum plants and their yields several relationships were tried. Among these, the one that worked best was:

$$Yr = A + B \; arc \; tan \; percent \; Nu, \qquad 2$$

where Yr is the relative yield, A and B are constants, and *arc tan percent* Nu is the arc whose tangent is the percentage of the respective nutrient in the plant on a dry-matter basis.

Equation 2 represents a straight-line relationship between relative yields and arc-tangent percentages. It can accordingly be written as

$$Yr = A + BX, \qquad 3$$

where $X = arc \; tan \; percent \; Nu$.

To fit equation 3 to the data, the percentage nutrient contents were, therefore, transformed into the arcs or angles with tangents equivalent to the given percentage contents. These angles were expressed in degrees. The fitting of this equation was then performed by calculating constants A and B according to the usual method of curve-fitting based on the principle of least squares.

According to this method,

$$B = \frac{SXYr - (SX)(SYr)/n}{SX^2 - (SX)^2/n} \qquad 4$$

and

$$A = SYr/n - BSX/n, \qquad 5$$

where SX = sum of values of X,
SYr = sum of values of Yr,
SX^2 = sum of squares of values of X,
$SXYr$ = sum of products of the corresponding values of X and Yr,
and n = total number of corresponding pairs of X and Yr values.

The values of A and B were calculated to fit the corresponding equations for nitrogen, phosphorus, and potassium to the data of table 1.

Nitrogen

$$n = 78; SX = 3{,}586.6; SYr = 6{,}154.5; S(XYr) = 300{,}108.7;$$

$$SX^2 = 175{,}504.6; SYr^2 = 557{,}563.0$$

$$B = \frac{S(XYr) - (SX)(SYr)/n}{SX^2 - (SX)^2/n} = \frac{300{,}108.7 - 282{,}996.5}{175{,}504.6 - 164{,}919.2} = 1.617$$

$$A = SYr/n - BSX/n = 6{,}154.7/78 - 1.617\ (3{,}586.6/78) = 4.56$$

$$Yr = A + BX = 4.56 + 1.617X_n$$ [3]

The statistical validity of this equation was determined by calculating the significance of the regression by the usual statistical techniques as follows:

Total sum of squares = $SYr^2 - (SYr)^2/n = 557{,}563.0 - (6{,}154.5)^2/78 = 71{,}949.3$

Reduction in sum of squares due to regression = $B\ [SXYr - (SX)(SYr)/n] = 1.617(17{,}112.2) = 27{,}670.4$

Reduced sum of squares = total sum of squares − reduction in sum of squares = 71,949.3 − 27,670.4 = 44,278.9

Reduced variance = reduced sum of squares/$(n - 2)$ = 44,278.9/76 = 582.6

F value for significance of regression = 27,670.4/582.6 = 47.50

The regression of relative yield on arc tangent percent nitrogen is significant at the 1-percent level.

Similar calculations were made for phosphorus and potassium.

Phosphorus

$$n = 73; SX = 1{,}610.0; SYr = 6{,}182.6; S(XYr) = 143{,}939.9;$$

$$SX^2 = 40{,}319.1; SYr^2 = 575{,}754.2$$

$$B = \frac{143{,}939.9 - (1{,}610.0)(6{,}182.6)/73}{40{,}319.1 - (1{,}610.0)^2/73} = 1{,}576$$

$$A = 6{,}182.6/73 - 1.576(1{,}610.0/73) = 49.94$$

$$Yr = 49.94 + 1.576X_p$$

[3] X_n stands for arc tangent percent nitrogen.

Total sum of squares = $575{,}754.2 - (6{,}182.6)^2/73 = 52{,}130.3$

Reduction in sum of squares due to regression = $1.576(7{,}583.9) = 11{,}952.2$

Reduced sum of squares = $52{,}130.3 - 11{,}952.2 = 40{,}178.1$

Reduced variance = $40{,}178.1/71 = 565.9$

F value for significance of regression = $11{,}952.2/565.9 = 21.12$

The regression of relative yield on arc tangent percent phosphorus is significant at the 1-percent level.

Potassium

$$n = 43; SX = 2{,}625.5; SYr = 4{,}008.3; S(XYr) = 246{,}698.9;$$

$$SX^2 = 162{,}530.8; SYr^2 = 382{,}220.9$$

$$B = \frac{246{,}698.9 - (2{,}625.5)(4{,}008.3)/43}{162{,}530.8 - (2{,}625.5)^2/43} = 0.882$$

$$A = 4{,}008.3/43 - 0.882(2{,}625.5/43) = 39.37$$

$$Yr = 39.37 + 0.882X_k$$

Total sum of squares = $382{,}220.9 - (4{,}008.3)^2/43 = 8{,}582.1$

Reduction in sum of squares due to regression = $0.882(1{,}959.6) = 1{,}728.4$

Reduced sum of squares = $8{,}582.1 - 1{,}728.4 = 6{,}853.7$

Reduced variance = $6{,}853.7/41 = 167.2$

F value for significance of regression = $1{,}728.4/167.2 = 10.34$

The regression of relative yield on arc tangent percent potassium is significant at the 1-percent level.

Summation

Summarizing, the formulas obtained relating yield and nutrient composition of the sorghum are:

Nitrogen	$Yr = 4.56 + 1.617\ X_n$
Phosphorus	$Yr = 49.94 + 1.576\ X_p$
Potassium	$Yr = 39.37 + 0.882_k$

The regressions of relative yield on arc tangent percent nutrients are all highly significant.

To test the adaptability of the arc tangent equation to data other than those for sorghum, experimental data were taken from the literature for corn, tomatoes, and barley. These experiments were performed under a wide variation of environmental and experimental conditions. The data used consisted of yields and the nutrient composition of the plants. The

arc-tangent formula was applied to the data of Krantz and Chandler (10)[4] for nitrogen on corn yields, Hoagland and Martin (7)[5] for potassium, Kraus and Kraybill (11) for nitrogen on tomato yields, and Macy (12)[6] for nitrogen on barley-grain yields. The regression coefficients were significant at the 1-percent level for all the data except the barley, in which case it was significant at the 5-percent level. The equations obtained were as follows:

Corn	$Yr = -232.35 + 4.72\ X_n$
Tomatoes	$Yr = 18.44 + 1.52\ X_n$
	$Yr = 51.04 + 0.59\ X_{k_2O}$
Barley	$Yr = 48.64 + 2.27\ X_n$

DISCUSSION

In selecting a certain type of equation or mathematical relationship to explain the relation between the nutrient contents of the plant tissues and the yield of a crop consideration should be given not only to the accuracy of the fit, or the precision of the equation to explain the desired relation, but also to the nature of the mathematical relationship and to the possible physical significance of the constants or parameters of that equation. The use of the straight-line equation to express the relationship would require the calculation of two constants, one of which would correspond to the yield obtained with zero content of the nutrient and the other would be the average constant increase in yield per unit increase in percentage nutrient content. This type of relationship requires the utilization of the concept that the relationship between the nutrient content and the yield content is one that holds from minus infinity to plus infinity.

This contrasts with the actual physical fact that nutrient contents cannot have a wider range than from 0 to 100 percent and yields cannot be negative. The use of the second-degree equation, the so-called parabola of the second order, requires the calculation of three constants, two of which are opposite in sign and none of which can be related easily to the physiological behavior of the plant. The only justification for the use of this equation, in case it is precise enough, would be the precision in fit. Even if the suitable equation were adapted to certain experimental data, it would be very difficult to make practical use of this equation, as its utilization would probably require the performance of a great many experiments before there would be the certainty that these constants would hold under different agricultural conditions.

[4] Table 2, Field No. C. F. 51 column and table 4, "June 22" column.
[5] Table 2, "No K pots" column.
[6] Table 3.

Through the change accomplished by converting percentages into angles where the arc tangent relationship is used, the apparent curvilinear relation between plant yield and composition is transformed into a straight-

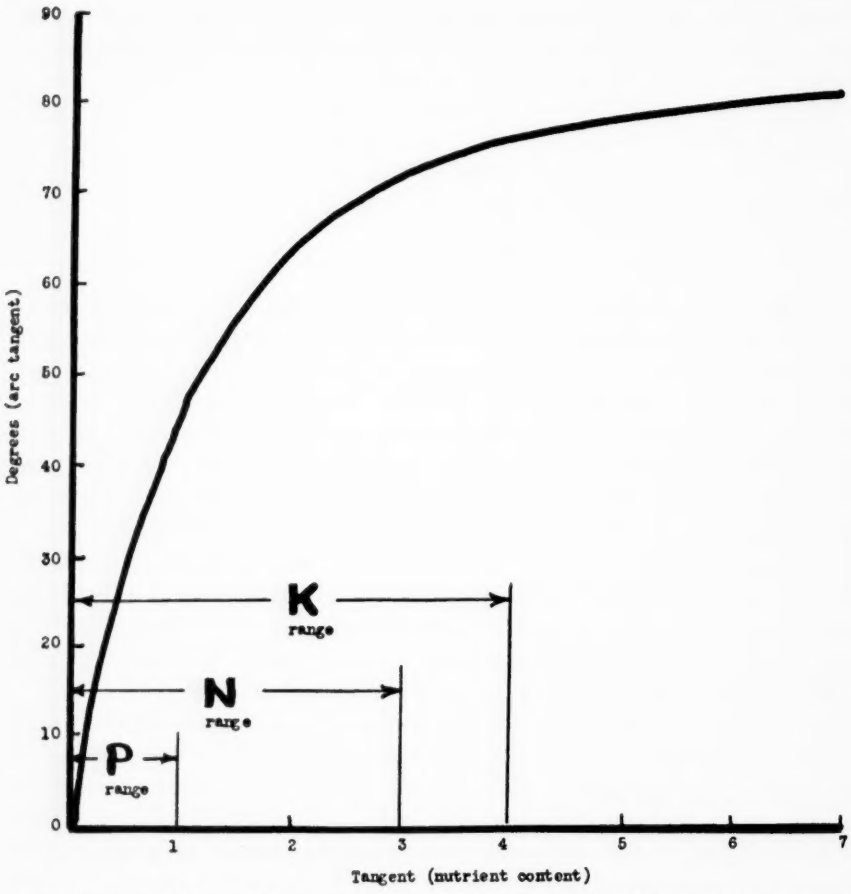

FIG. 1.— Variation of the arc tangent with the tangent and the nutrient ranges found in sugarcane leaf samples.

line relationship. Furthermore, there are limits to the values within which this relation holds, since the angle must be at all times between 0 and 90°. Therefore, this also limits the values of the relative yields which, of course, can vary only from 0 to 100 percent. The values of the tangent change slowly in the interval from 0 to 4, whereas the values of the corresponding angles vary from 0 to approximately 80 (see fig. 1). As the majority of the economic crops give nutrient-content values in the 0- to 4-percent range,

and relative-yield values in the 0- to 80-percent range, we have in the arc-tangent concept a sensitive means of relating small increases in nutrient content with larger yield increments.

Furthermore, for the practical utilization of this equation, that is, in order to make decisions as to which one of a number of possible nutrients should be applied in greater amounts to a soil, the composition of the plant should be sufficient to indicate the fertility status of the growth medium. The use for this purpose of techniques which depend on yields, like the Mitscherlich's method of soil-testing, require observations under two or more fertilizer conditions so as to eliminate the effect of those environmental factors other than that of the nutrient under study. With respect to the mathematical calculations necessary to fit and interpret the arc-tangent equation they are almost as simple as the equation of the straight line and considerably simpler than the equation of the second degree, since the equation becomes a linear one when the percentage content is transformed into the angle.

The equation $Yr = A + BX$ seems to hold for each one of the three major fertilizer elements: Nitrogen, phosphorus, and potassium. Moreover, the fitted equation holds for different soils and fertilizer applications, at different sand-to-soil ratios, and when a crop is grown in different seasons of the year. Furthermore, the material analyzed was representative of whole sorghum plants at the end of their vegetative growth, that is, when they were about to head. At this stage of growth it would be too late in most instances to utilize this information in making decisions as to the quantity and quality of fertilizers required by that crop. Other data available at present, however, tend to indicate that this same type of equation holds for other crops even better when the composition of the plant at an early stage of the growth period is used. We hope to present this information, as well as data on the effect of age of crop on nutrient content, in a later paper. For perennial crops, or crops with a long period of growth, the use of this technique would be specially valuable.

SUMMARY

1. Although much work has been done on the relation between the composition of a plant and its yield, very little specific information exists about the quantitative relationship between plant yields and plant composition.

2. Using data from hegari sorghum grown at various nutrient levels on leading Puerto Rican soils, a general mathematical equation was established relating the sorghum yield to its nutrient composition. The equation is:

$$Yr = A + B \text{ arc tan percent } Nu$$

where Yr is the relative yield of the crop, A and B are constants, and *arc tan percent* Nu is the arc whose tangent is the percentage of the respective nutrient in the plant on a dry-matter basis. Substituting X for arc tangent percent Nu, it can be expressed in the form of the linear equation

$$Yr = A + BX.$$

3. The arc tangent equation was developed from 50 experiments with different soil-to-sand ratios and different growing seasons, using samples of 28 different soil series. The equations obtained relating yield to the nutrient contents of hegari sorghum were:

For nitrogen, $Yr = 4.56 + 1.617\ X_n$
For phosphorus, $Yr = 49.94 + 1.576\ X_p$
For potassium, $Yr = 39.37 + 0.882\ X_k$.

The explanation of yield differences offered by these equations were highly satisfactory as indicated by the fact that the regressions were significant at the 1-percent point.

4. The use of the arc tangent equation to relate yield and nutrient composition was shown to have many practical advantages over other possible mathematical equations which might be used. The primary value of the use of the arc tangent equation is that it makes use of plant composition and does not depend on yields. Only one value obtained for any particular nutrient content is needed to make an estimate as to the sufficiency of the particular nutrient in the growth medium. Other methods usually require field experiments with samples taken at various fertility levels.

5. The arc tangent equation was applied to the data of Krantz and Chandler for corn, Hoagland and Martin and Kraus and Kraybill for tomatoes, and Macy for barley. It gave a highly satisfactory explanation of the variations in yield, as witnessed by the fact that the regressions were statistically significant at the 1-percent point in all but the last case, in which it was significant at the 5-percent point.

RESUMEN

1. Aunque se ha hecho mucho trabajo con respecto a la relación entre la composición química de la planta y el rendimiento de la misma, al presente existe muy poca información en cuanto a la relación cuantitativa entre estos dos factores.

2. Usando datos obtenidos con sorgo hegari crecido en varios niveles de abonamiento en los principales suelos de Puerto Rico, se ha establecido una ecuación matemática general que relaciona el rendimiento de sorgo con su composición química. Esta ecuación es,

$$Yr = A + B \textit{ arco tangente } N_u,$$

en donde Yr es el rendimiento relativo de la cosecha, A y B son constantes y *arco tangente* N_u es el arco cuya tangente es el por ciento del elemento nutritivo respectivo en la planta a base seca. Substituyendo X por arco tangente N_u la ecuación matemática mencionada arriba puede transformarse en la ecuación de la línea recta

$$Yr = A + BX.$$

3. La ecuación del arco tangente fué desarrollada de 50 experimentos llevados a cabo con proporciones distintas de suelo y arena en diferentes épocas de crecimiento y usando suelos de 28 series de Puerto Rico. Las ecuaciones que relacionan el rendimiento con el contenido de elementos nutritivos por el sorgo hegari fueron:

para nitrógeno: $Yr = 4.56 + 1.617\ X_n$;
para fósforo: $Yr = 49.94 + 1.576\ X_p$;
y para potasio: $Yr = 39.27 + 0.882\ X_k$.

Las explicaciones de las diferencias en rendimiento ofrecidas por estas ecuaciones fueron satisfactorias en alto grado según lo indica el hecho de que las regresiones fueron significativas en el punto del 1 por ciento.

4. El uso de la ecuación del arco tangente para relacionar el rendimiento con la composición química de la planta ha demostrado tener un número de ventajas prácticas sobre otras ecuaciones matemáticas que podrían usarse para este propósito. El valor principal del uso de la ecuación del arco tangente es que hace uso de la composición química de la planta y no depende de rendimientos. Para hacer un estimado en cuanto a la suficiencia o deficiencia de un elemento nutritivo en particular en el medio de crecimiento hace falta solamente conocer el contenido de este elemento nutritivo por la planta. Los otros métodos que pueden usarse para este propósito requieren rendimientos obtenidos bajo varios niveles de fertilidad.

5. La ecuación del arco tangente fué ajustada a los datos experimentales de Krantz y Chandler con maíz, Hoagland y Martin y Kraus y Kraybill con tomates, y Macy con cebada. La ecuación explicó satisfactoriamente en alto grado las variaciones en rendimiento obtenidas en estos experimentos como lo demuestra el hecho de que las regresiones fueron significativas estadísticamente en el punto del 5 por ciento en el último caso y en el punto del 1 por ciento en los demás.

LITERATURE CITED

1. Borden, R. J., A search for guidance in the nitrogen fertilization of the sugarcane crop, Pt. I, The plant crop, *Hawaiian Planters' Rec.* **46** 191–238 1942.
2. ——, A search for guidance in the nitrogen fertilization of the sugarcane crop, Pt. II, The first ratoon crop, *Hawaiian Planters' Rec.* **48** 271–306 1944.
3. ——, A search for guidance in the nitrogen fertilization of the sugarcane crop, Pt. III, The second ratoon crop, *Hawaiian Planters' Rec.* **50** 161–200 1946.

4. Capó, B. G., Available nutrient contents of Puerto Rican soils as determined by pot tests, thesis presented to the Faculty of the Graduate School of Cornell University for the degree of Doctor of Philosophy (unpublished), 1942.
5. ——, A modification of Mitscherlich's method for the determination of the nutrient contents of a soil, *J. Agr. Univ. P. R.* **22** 138–70 1938.
6. Clements, H. F. and Kubata, T., The primary index, its meaning and application to crop management with special reference to sugarcane, *Hawaiian Planters' Rec.* **47** 257–97 1943.
7. Hoagland, D. R. and Martin, J. C., Absorption of potassium by plants in relation to replaceable, nonreplaceable and soil solution potassium, *Soil Sci.* **36** 1–33 1933.
8. Innes, R. F., Plant analysis in relation to the nutrition of sugarcane in Jamaica, *Proc. 1948 Meet. B. W. I. Sugar Technologists* 92–114 1948.
9. Jenny, H., Factors of Soil Formation, McGraw-Hill Book Co., Inc., New York, N. Y., 1941.
10. Kranz, B. A. and Chandler, W. V., Lodging, leaf composition, and yields of corn as influenced by heavy applications of nitrogen and potash, *J. Amer. Soc. Agron.* **43** 547–49 1951.
11. Kraus, E. J. and Kraybill, H. R., Vegetation and reproduction with special reference to the tomato, *Oreg. Agr. Exp. Sta. Bul.* **149** 1918.
12. Macy, P. R., The quantitative mineral requirement of plants, *Plant Physiol.* **11** 749–64 1936.
13. Mitchell, H. L. and Chandler, R. F. Jr., The nitrogen nutrition and growth of certain deciduous trees of northeastern United States, *Blackrock Forest Bul.* **11** 1939.
14. Thomas, W., Foliar diagnosis: principles and practices, *Plant Physiol.* **12** 571–99 1937.
15. Tyner, E. H., The relation of corn yields to leaf nitrogen, phosphorus, and potassium content, *Proc. Soil. Sci. Soc. Amer.* **11** 317–23 1946.
16. Ulrich, A., Plant analyses as a diagnostic procedure, *Soil Sci.* **55** 101–12 1943.

IRON CHLOROSIS ON *Dracaena sanderiana*

George Samuels and Héctor R. Cibes[1]

INTRODUCTION

The *Dracaena sanderiana* is a tall-stemmed, erect, unbranched ornamental plant with long lanceolate leaves 5 to 9 inches long and ¾ to 1¼ inches broad, gradually tapering to a sharp point with broad longitudinal bands of white at the margin and often other stripes further in the leaf. It is grown by the ornamental plant growers of Puerto Rico for export to the United States for the greenhouse and florist trade. In 1952, it was estimated that over 1,000,000 plants were shipped to the United States with a value of $100,000. As the demand for *sanderianas* is increasing, the present export market demand is well over 2 or 3 times the shipments of 1952.

A chlorosis of *sanderiana* was noted by some of the growers. At first not much attention was given to this chlorosis because of its limited appearance. However, with increased production of *sanderianas* for the export market and the more frequent cutting of stock plants, the extent of the chlorosis became greater. By 1952, many leading growers were threatened with limited or no production because of the chlorosis. The Agricultural Experiment Station of the University of Puerto Rico, in cooperation with the Agricultural Extension Service, as requested by the ornamental plant growers of Puerto Rico, began work on this problem in the summer of 1952.

SYMPTOMS AND NATURE OF THE CHLOROSIS

The chlorosis of *sanderiana* consists of a yellowing of the green portion of the leaf. In severe cases, the chlorosis occurs to such an extent that no chlorophyll is seen, and the entire leaf becomes ivory-white. In the earlier stages the chlorosis is evident on the youngest leaves of the plant. With age and increasing severity it moves down to the older leaves until the entire plant is chlorotic. Growth becomes limited, few new suckers appear, but no severe stunting occurs at first. There are no mottled areas or necrotic spots on the leaves, and no wrinkling occurs.

Examination of the roots reveals no evidence of insect or nematode damage. The roots of the chlorotic plants generally are smaller in volume

[1] Plant Physiologist and Associate Plant Physiologist, respectively, Agricultural Experiment Station, University of Puerto Rico, Río Piedras, P. R. The authors wish to acknowledge with thanks the cooperation and suggestions of Charles F. Pennock of Pennock Gardens, Miguel A. Díaz, Horticultural Specialist of the Agricultural Extension Service of the Agricultural Experiment Station, and the ornamental plant growers of Puerto Rico for plant material.

and have fewer fine-branching rootlets than healthy plants of corresponding age and size.

The symptoms displayed are indicative of iron chlorosis. The occurrence of the chlorosis first in the younger leaves then in the older is strongly characteristic of iron chlorosis where the relatively immobile iron in the plant does not move to the newer leaves where it is needed. Ferrous sulfate solutions painted on the leaf relieved the chlorosis, and verified the suspicion that it was caused by a deficiency of iron.

In the summer of 1952, a survey was made by the senior author with the aid of Miguel A. Díaz of the Agricultural Extension Service to determine what environmental conditions were responsible for the chlorosis of *sanderiana* in Puerto Rico. Field trips were made to collect plant and soil samples from *sanderiana* growers where chlorosis was present and from growers who had none. The survey revealed the following:

1. The chlorosis was present in *sanderianas* growing in soils with pH's ranging from 4.2 to 7.5. The majority of the soils were below a pH of 6.0.
2. The soil textures ranged from loamy sands to heavy clays with the majority on sandy soils.
3. Poor drainage was present in many chlorotic beds. This usually was caused by a heavy clay subsoil extending 6 to 10 inches below the sandy surface soil.
4. In some cases there were healthy *sanderianas* growing next to chlorotic ones.
5. The use of commercial fertilizers containing nitrogen, phosphorus, or potassium did not seem to influence the chlorosis significantly.
6. Tip cuttings taken from chlorotic *sanderianas* and rooted in a well-drained, fertile soil recover and new growth showed no evidence of chlorosis.
7. If old plantings were uprooted after 5 to 6 years and the roots were trimmed and replanted in new soil, the new growth was free of chlorosis.
8. The older *sanderiana* stock cut for many years had many large roots with an orange-brown coating. In general, these roots did not seem to possess much power of absorbing water and nutrients. It appeared as if the small rootlets branching from these main roots did the work. It was observed that old chlorotic plants did not have sufficient new root area to support the number of above-ground stems that were growing.

It appeared from the survey that poor drainage and limited root systems were preventing enough available iron from entering into the *sanderiana* plant. There were no indications of a lime-induced chlorosis from high pH (above 7.5) nor of salt accumulations. With these facts in mind a greenhouse experiment was started to determine how the iron deficiency in *sanderiana* might best be corrected.

EXPERIMENTAL PROCEDURE

Rooted tip cuttings of *Dracaena sanderiana* were placed in 2-gallon glazed pots filled with cleaned white quartz sand. The plants were grown for 1 month with only distilled water added, then 1 month with a complete nutrient solution, minus iron. After this 2-month period of exhausting the iron reserve of the plant, a moderate iron chlorosis developed in all plants

TABLE 1.—*The influence of various iron salts on the control of iron chlorosis in* Dracaena sanderiana

Treatment letter	Treatment[1]	Rate of application	Degree of chlorosis	Appearance of the leaf
A	No iron	0	High	Light yellowish-green
B	$FeSO_4$ spray on leaves	2 lb. $FeSO_4$ per 100 gal. of water plus 1 lb. lime	Moderate	Dark-green spots with rest of leaf yellowish-green and covered with reddish-brown spray residue
C	Fe EDTA in nutrient solution to roots	5 p.p.m. of Fe EDTA (12 percent as metallic iron)	Slight	Green with slight yellow green in areas
D	Fe EDTA spray on leaves	1 lb. of Fe EDTA (12 percent as metallic iron) per 100 gal. of water	None	Dark-green
E	$FeSO_4$ in nutrient solution to roots	5 p.p.m. as Fe	None	Do.

[1] All received a complete nutrient solution including N, P, K, Ca, Mg, S, Zn, Mn, Cu, B, and the Fe was added as indicated.

typical of the *sanderiana* chlorosis noted under shade-house conditions in the field.

Differential treatments were then applied as shown in table 1. All plants received a complete nutrient solution containing N, P, K, and the minor elements Ca, Mg, Zn, Cu, B, and S. Iron in various forms was given in all treatments except A. Ferrous sulfate was used as a spray in treatment B, and in solution in treatment E. A new source of iron, the ferric salt of ethylenediamine tetraacetic acid, Fe-EDTA,[2] was utilized in two treatments to see whether it was more efficient than the normally used ferrous

[2] The commercial form of the salt used was Sequestrene NaFe (12.0 percent Fe as metallic) available from the Alrose Chemical Co., New York, N. Y.

sulfate. In treatment C the Fe-EDTA was supplied in solution, and in treatment D it was used as a spray.

RESULTS

The results of the various treatments are given in table 1 and figure 1. The no-iron-treatment *sanderianas* were chlorotic (see fig. 1, A). The

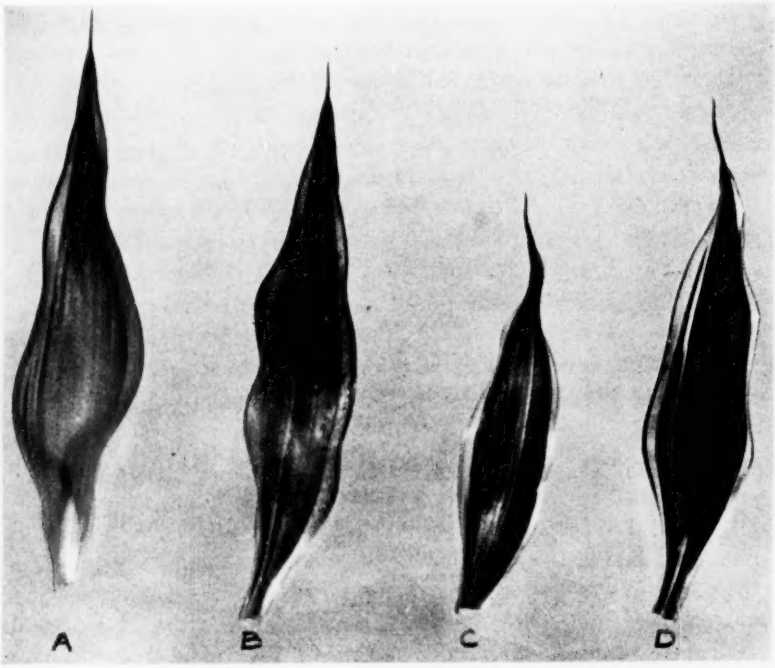

FIG. 1.—The influence of various sources of iron on *Dracaena sanderiana* grown in the greenhouse: A, Chlorotic *sanderiana* leaf which received no iron in its nutrient solution; B, *sanderiana* leaf sprayed with solution of ferrous sulfate, showing spotting and iron-stain residue; C, *sanderiana* leaf which received Fe-EDTA (chelated iron) in solution, showing improved coloring but not complete recovery; D, *sanderiana* leaf sprayed with Fe-EDTA showing healthy green leaf with no visible evidence of chlorosis.

chlorosis was evident in the new leaves at the top of the plant. Here almost the entire leaf was yellowish-green. The older leaves, although not chlorotic, were lighter green in color, and the plants did not have a healthy appearance suitable for export.

Where iron was supplied as ferrous sulfate in solution (treatment E), the plants gave no evidence of chlorosis, and were healthy in appearance with dark-green leaves. This confirmed that control of the chlorosis could

be obtained if iron were made available to the plant. However, the use of ferrous sulfate as a soil treatment is limited, as the very soil conditions which limit the intake of available iron to the *sanderiana* also fix the iron added to the soil in an unavailable form. For this reason, ferrous sulfate was then tried as a spray (treatment B).

The application of the iron as a ferrous sulfate spray gave unsatisfactory results from a commercial standpoint. As can be seen in figure 1, B, the leaf had a residue which made the plant unsuitable for sale as an ornamental. The residue consisted of a reddish-brown coating on the leaf left by the spray. The residue could be removed by washing only with difficulty, which meant extra labor costs for the grower if the spray were used. Even more objectionable was the uneven coloring obtained with use of the ferrous sulfate spray. The leaves developed dark-green spots while other areas still remained chlorotic. This spotting gave the plant an unsatisfactory appearance for commercial sales purposes. The spotting appeared to be caused by an uneven absorption of the spray from the glossy surface of the *sanderiana* leaf. The dark-green spots occurred near stomatal openings where the intake of the iron was more rapid.

Commercial plantings of chlorotic *sanderianas* exhibited this spotting effect when sprayed with ferrous sulfate. However, new growth from these plants was very healthy and showed no chlorosis. The older chlorotic plants never recovered their appearance sufficiently for sales purposes and could be used only as stock plants. Evidence of spray injury with ferrous sulfate sprays was encountered in trials on *sanderianas* and other ornamentals near the sprayed beds when rates above 5 pounds of ferrous sulfate per 100 gallons of water were used.

The use of Fe-EDTA, the chelated iron source, gave very promising control of iron chlorosis. When used as a spray once weekly, 1 pound of the Fe-EDTA (12 percent as metallic iron) per 100 gallons of water for 2 weeks gave complete control as can be seen in figure 1, D. The leaves were dark green, and the entire plant was healthy in appearance. Growers who saw the plants stated that they were of very high quality and satisfactory for export sales.

There was no evidence of any spotting effect or residue as when ferrous sulfate was used. Preliminary trials on commercial plantings showed that if the spray application was not uniform for highly chlorotic *sanderianas* a certain amount of spotting occurred. The greener areas of the leaf were much larger than when ferrous sulfate sprays were used, and after continued spraying the areas merged to produce a normal leaf. The fieldwork indicated that higher rates of Fe-EDTA are usually needed for control of the chlorosis than were required in the greenhouse experiment, and that thorough sprayings must be made. The use of a sticker is recommended.

A detergent (Dreft) was utilized as the sticker in greenhouse work with satisfactory results.

Although complete studies in the field have not been finished, preliminary trials by growers indicate that 2 to 4 pounds of Fe-EDTA (12 percent as metallic iron) per 100 gallons of water give satisfactory control when sprayed thoroughly on chlorotic *sanderianas*. Trials have shown that rates up to 15 pounds of Fe-EDTA per 100 gallons of water neither produced leaf injury nor left insoluble residues on the leaf. More frequent applications were needed for highly chlorotic *sanderianas* than for those tested under greenhouse conditions.

FE-EDTA gave satisfactory control over a long period of time when applied to the roots of the plant in solution; however, recovery was not as fast as when the plants were sprayed. At 4 weeks control was achieved with the spray, while the solution had still not given an entirely satisfactory green color (see fig. 1, C). One month later no visual differences could be detected between the two Fe-EDTA treatments. It appears that for rapid control of the chlorosis, Fe-EDTA in spray form is best. Preliminary field trials showed that Fe-EDTA applied to the soil, and worked into it near the plant, controlled chlorosis in the new growth, but the old chlorotic leaves did not show a full recovery for quite a long while. Chlorotic tip cuttings rooted in Fe-EDTA-treated soils recovered rapidly.

DISCUSSION

The use of Fe-EDTA to control iron chlorosis is not new. It was used by Jacobson (2)[3] in nutrient-solution work in the greenhouse and by Stewart and Leonard (3) for control of iron chlorosis in citrus. EDTA is an organic complex (ethylenediamine tetraacetic acid) which is known to organic chemist as a chelating agent, a name derived from the Greek word meaning "claw". The organic molecule of EDTA acts like two jaws and removes metal ions from solutions, and the reaction is reversible (1). Thus, when chelated with EDTA to give Fe-EDTA, iron can be released to the plant without being fixed by the soil as are ordinary iron salts added to the soil.

RECOMMENDATIONS

The results of the greenhouse experiments reported here and of preliminary field trials suggest the following measures for the control of iron chlorosis of *Dracaena sanderiana* in Puerto Rico:

1. Plant *sanderianas* in well-drained soils.
2. If heavy cutting of stock plants is practiced, high rates of fertilizers

[3] Numbers in parentheses refer to Literature Cited, p. 272.

(major and minor elements) are needed to offset the heavy drain of nutrients on the stock plant.

3. Forking the soil, or spading so as to prune old inactive roots and force new roots, is recommended for old-stock plantings.
4. Two to four pounds of Fe-EDTA (12 percent as metallic iron) per 100 gallons of water should be used as a spray for chlorotic plants.
5. Highly chlorotic plants should be sprayed once a week for 1 month, followed by spraying once a month until chlorosis is under control.
6. For preventive control of chlorosis in soils in which *sanderianas* have shown chlorosis, spray the plants once every 3 months, or apply Fe-EDTA to the soil mixed in the fertilizer at the rate of 25 pounds per acre.

SUMMARY

A study of a chlorosis on *Dracaena sanderiana* in Puerto Rico disclosed the following facts:

1. The chlorosis which consists of a yellowing of the younger rather than the older leaves of the *sanderiana* is caused by a lack of available iron.
2. The chlorosis was found in soils with pH's ranging from 4.2 to 7.5 and with textures from loamy sands to heavy clays. It was more prevalent on poorly drained soils.
3. The use of ferrous sulfate sprays gave unsatisfactory results because of a spotting or uneven greening of the leaf and an unsightly residue which could be removed only with difficulty by washing.
4. The use of Fe-EDTA (12 percent as metallic iron), an organic iron complex as a spray (1 pound per 100 gallons) gave satisfactory control without leaving any spray residues or causing spotting.
5. Fe-EDTA gave satisfactory results when applied to the roots in solution, but took longer to work than did the Fe-EDTA spray.
6. General recommendations are given for the control of iron chlorosis in *sanderianas*.

RESUMEN

El estudio de la clorosis que afecta a la *Dracaena sanderiana* en Puerto Rico ha revelado lo siguiente:

1. La clorosis, que es un amarillamiento de las hojas jóvenes de la *sanderiana*, la causa una falta de hierro asimilable en la planta.

2. La clorosis fué hallada en suelos con pHes que variaron desde 4.2 hasta 7.5 y en texturas desde las arenas margosas hasta las arcillas pesadas. Estas últimas fueron las más predominantes en los suelos con desagüe pobre.

3. El uso del sulfato de hierro en aspersiones dió resultados poco satisfactorios debido a que produjo una especie de moteado o reverdecimiento irregular de las hojas y a que deja, además, un residuo de fea apariencia, el cual se hace difícil remover aunque se lave la hoja.

4. El uso de hierro en la forma orgánica EDTA (12 por ciento hierro metálico) en aspersiones (1 libra por cada 100 galones) dió resultados satisfactorios en el control de la clorosis sin dejar residuos o producir moteo.

5. Cuando el hierro EDTA se aplicó en solución a las raíces de las plantas, dió resultados satisfactorios, pero tomó más tiempo en actuar que cuando se usó en aspersiones.

6. Se hacen recomendaciones generales para el control de la clorosis producida por la falta de hierro en la *sànderiana.*

LITERATURE CITED

1. Alexander, C. C. and Walsh, D. S., New Chemical Agent makes possible complete control of iron chlorosis, *Agr. Chemicals* **7** (7) 36–8 1952.
2. Jacobson, L., Maintenance of iron supply in nutrient solutions by a single addition of ferric potassium ethylenediamine tetraacetate, *Plant Physiol.* **26** 411–13 1951.
3. Stewart, I. and Leonard, C. D., Iron chlorosis—its possible causes and control, *Citrus Mag.* **14** (10) 22–5 1952.

POTASSIUM COMPETITION IN A KUDZU-MERKER GRASS ASSOCIATION

George Samuels and Pablo Landrau, Jr.[1]

INTRODUCTION

The use of tropical kudzu (*Pueraria phaseoloides* (*javanica*) Benth.) as a legume in Puerto Rico has shown great promise for soil-erosion control, pasture, and silage. A chlorosis of tropical kudzu has been noted in several instances, when it was grown in association with grasses as a pasture crop, especially in the area of Río Piedras. This chlorosis was in evidence in field experiments with grass-legume associations on Fajardo clay at the García Méndez fields of the Agricultural Experiment Station at Río Piedras. It was brought to the attention of the authors because of a possibility that the chlorosis might have been caused by minor-element deficiencies and as they were then engaged in research on the minor-element needs of Puerto Rican crops.

An examination of the kudzu-Merker grass association revealed that the kudzu showed signs of chlorosis in the leaves, but there was no particular evidence of a chlorotic condition on the Merker grass (*Pennisetum purpureum* var. *Merkerii* Schumaker). The chlorosis on the kudzu was evidenced by a yellowing of the leaves, the older leaves being affected first. The leaves were yellow with some of the veins dark green. Some highly chlorotic leaves had a yellowish-brown marginal scorch. In general, the chlorosis was suggestive of potassium deficiency (4)[2].

A potassium deficiency had been noted before by the authors on kudzu growing as a ground cover in a coconut plantation at Dorado on a Cataño loamy sand. Kudzu, however, had failed to give significant yield responses on the Fajardo clay soils when potash was applied (5) in an experiment close to the site of the chlorotic kudzu-Merker grass association.

The question now arose whether the chlorosis occurred on the kudzu only when it was grown in association with a grass and not when it was seeded by itself on the Fajardo clay. It was also to be determined whether the deficiency caused the chlorosis, and how this might be corrected. An experiment was established at the García-Méndez field at Río Piedras to answer these questions.

PROCEDURES

The experiment consisted of eight treatments replicated five times in a split-plot design. The soil used was a Fajardo clay, an acid lateritic clay

[1] Plant Physiologist and Assistant Agronomist, respectively, Agricultural Experiment Station, University of Puerto Rico, Río Piedras, P. R.

[2] Numbers in parentheses refer to Literature Cited, pp. 281–2.

with a pH 5.5. The treatments used are given in table 1. All treatments received 50 pounds of N per acre as ammonium sulfate and 100 pounds of P_2O_5 per acre as superphosphate (20 percent P_2O_5). The plots were fertilized

TABLE 1.—*The effect of fertilizers on the yields of tropical kudzu and Merker grass grown on Fajardo Clay at García-Méndez*

No.	Treatments[1] Pounds per acre	Yields of forage per acre, (green weight)				
		First cutting			Second cutting, Kudzu and Merker grass	Total kudzu and Merker
		Kudzu	Merker	Kudzu and Merker grass		
		Tons	*Tons*	*Tons*	*Tons*	*Tons*
1	Kudzu	2.24	0	2.24	1.64	3.88
2	Kudzu + 300 lbs. MgO	2.56	0	2.56	2.13	4.69
3	Kudzu + 50 lbs. borax	2.49	0	2.49	1.73	4.22
4	Kudzu + 300 lbs. K_2O	2.36	0	2.36	1.94	4.30
A	Mean of kudzu treatments	2.41	0	2.41	1.86	4.27
5	Kudzu and Merker grass	1.99	6.08	8.07	10.65	18.72
6	Kudzu and Merker grass + 300 lbs. MgO	1.50	6.39	7.89	10.28	18.17
7	Kudzu and Merker grass + 50 lbs. borax	1.42	7.19	8.61	11.44	20.05
8	Kudzu and Merker grass + 300 lbs. K_2O	2.51	5.50	8.01	12.82	20.83
B	Mean of kudzu and Merker grass treatments	1.86	6.29	8.15	11.30	19.45
Least significant differences needed for comparison of:						
Mean of A or B:	5-percent point	0.48		2.42	2.36	2.28
	1-percent point	.80		4.02	3.91	3.87
Treatments within A or B:	5-percent point	.80		1.26	2.31	1.86
	1-percent point	1.09		1.79	3.12	2.19

[1] All treatments received 50 lb. of N and 100 lb. of P_2O_5 per acre.

before planting; they were 8 by 20 feet, or $\frac{1}{272}$ of an acre in area, with plants set out 2 feet between rows and 3 feet between plants. The kudzu was germinated in paper cups filled with soil from the field and then transplanted into the field after the plants were 3 weeks old, on December 13, 1949. The Merker grass was planted from cuttings on March 16, 1950, after the kudzu had established a good stand.

The treatments were divided between kudzu growing alone and a kudzu-

Merker grass association. The potassium treatments were utilized to determine whether the kudzu chlorosis was due to a potash deficiency. Magnesium in the form of the oxide was employed, as it was thought that certain of the symptoms, such as the chlorosis between the veins, appeared to be similar to those of a magnesium deficiency, and that, perhaps, there was a combined potassium and magnesium deficiency. The borax treatment was added because of the reported low boron content of the Fajardo clay as determined by the Soil Department using the sunflower-indicator test.

The first cutting of the experiment was harvested on July 18, 1950, at an age of 7 months. The experiment was then fertilized again as indicated, and a second cutting was made on December 12, 1950, at an age of 5 months. A representative sample was taken from the harvested plots and dried for calculations of the moisture content, dry-weight yields, and protein analyses.

RESULTS

Yields

The yields of kudzu growing alone were not influenced significantly by the treatments applied (see table 1). When grown in association with Merker grass, the kudzu gave half a ton more green forage in the first cutting when fertilized with potash (treatment 8 minus treatment 5, table 1). There was a reduction in yield of the Merker grass of 0.58 ton for the same treatment, so that the total yields of the combined kudzu and Merker grass showed no gain from the use of potash for the first cutting. In the second cutting, the combined kudzu-Merker grass yields rose 2.17 tons of green forage per acre when potash was applied. Unfortunately, the weights of the kudzu and Merker grass were not taken separately because of an error in procedure, therefore, it was impossible to determine whether the yield increases were in kudzu or Merker grass or both.

Kudzu grown alone decreased in yield for all treatments for the second cutting which grew for 5 months as compared with 7 months for the first. The combined kudzu-Merker grass treatments, however, all gave higher yields in the second cutting than in the first.

In the first cutting the kudzu definitely yielded less when grown in association with the Merker grass than when grown alone. The only treatment which produced no reduction was potash applications (treatment 8 compared to treatement 4, table 1).

If the potash treatments are excluded from the means of the first cutting, the kudzu growing alone had a mean yield of 2.43 tons of green forage per acre; when growing with Merker grass its yield was 1.64 tons per acre. The reduction in yield of kudzu growing in association with Merker grass, except where potash was applied, plus the increased yields of the kudzu-Merker

grass combination when fertilized with potash, suggested that potash was of value to kudzu-Merker grass associations.

The use of borax or magnesium oxide did not appreciably influence yields of either kudzu or kudzu-Merker grass (see table 1).

TABLE 2.—*The effect of fertilizers on the nutrient content of tropical kudzu and Merker grass grown on Fajardo clay at García Méndez*

No.	Treatments (pounds per acre)	Plant material	Nutrient content of plant material (dry weight)							
			First cutting				Second cutting			
			Protein	Nitrogen	Phosphorus	Potassium	Protein	Nitrogen	Phosphorus	Potassium
			Per-cent	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*
1	Kudzu	Kudzu	20.7	3.31	0.45	3.60	15.6	2.50	0.34	3.04
2	Kudzu + 300 lbs. MgO	do.	21.1	3.38	.45	3.59	17.4	2.78	.32	2.21
3	Kudzu + 50 lbs. borax	do.	21.8	3.48	.47	2.95	18.7	2.99	.33	2.53
4	Kudzu + 300 lbs. K_2O	do.	19.8	3.16	.43	3.42	17.8	2.85	.32	3.36
	Mean of Kudzu treatments	do.	20.9	3.33	0.45	3.39	17.4	2.78	0.33	2.78
5	Kudzu and Merker grass	Kudzu	16.9	2.70	0.41	3.08	16.8	2.68	0.30	2.80
		Merker grass	9.1	1.45	.31	2.30	12.3	1.97	.39	1.97
6	Kudzu and Merker grass + 300 lbs. MgO	Kudzu	16.7	2.67	.38	2.26	19.0	3.04	.27	2.17
		Merker grass	8.2	1.31	.27	1.91	13.8	2.20	.38	2.50
7	Kudzu and Merker grass + 50 lbs. borax	Kudzu	17.2	2.75	.38	2.27	19.7	3.15	.30	2.31
		Merker grass	8.3	1.32	.28	2.21	11.6	1.86	.40	2.27
8	Kudzu and Merker grass + 300 lbs. K_2O	Kudzu	15.4	2.46	.38	2.53	16.3	2.61	.29	2.85
		Merker grass	7.2	1.15	.27	2.97	12.5	2.00	.39	2.97
	Mean of kudzu treatments		16.6	2.64	0.39	2.54	17.9	2.87	0.29	2.53
	Mean of Merker grass treatments		8.2	1.31	0.28	2.35	12.5	2.01	0.39	2.43

Chemical Analyses

The analyses of the first and second cuttings of the kudzu and the Merker grass are given in table 2. There was no appreciable difference in respect to protein nitrogen in the first cutting when the kudzu was grown in association with Merker grass, but this was not evident in the second cutting. A reduction in the protein content of kudzu growing with Merker grass was also noted by Warmke *et al.* (7) for a crop grown in Puerto Rico. The nitrogen and protein values were lowest in all cases for the potash treatments in

the first cutting. In the second cutting, the nitrogen values were lowest for the kudzu grown without potash (treatment 1, table 2).

There was no apparent change in the phosphorus content of either the

FIG. 1.—A potassium chlorosis of tropical kudzu growing in association with Merker grass.

kudzu or Merker grass that could be attributed to any of the treatments. The kudzu growing alone and with Merker grass decreased in phosphorus content at the second cutting. Merker grass increased in phosphorus content in the second cutting.

The potassium analyses revealed no consistent difference attributable to the treatments when the kudzu was grown alone. However, when it was

grown in association with the Merker grass, the kudzu had lower potassium values in both cuttings. The kudzu-Merker grass treatments (treatment 8 minus treatment 5, table 2) produced higher potassium values for the

TABLE 3.—*The nutrient content of tropical kudzu leaves with and without deficiency symptoms, growing alone and with Merker grass*

No.	Treatments[1]	Condition of leaf[2]	Nutrient content of kudzu (dry weight)		
			Nitrogen	Phosphorus	Potassium
			Percent	*Percent*	*Percent*
1	Kudzu	Normal	3.64	0.40	2.20
		Chlorotic	3.49	.31	1.28
2	Kudzu and Merker grass	Normal	3.08	.36	2.75
		Chlorotic	3.11	.30	1.50
3	Kudzu + 300 lbs. MgO	Normal	3.62	.37	2.73
		Chlorotic	3.49	.33	1.79
4	Kudzu and Merker grass + 300 lbs. MgO	Normal	3.11	.31	2.11
		Chlorotic	3.14	.29	1.20
5	Kudzu + 50 lbs. borax	Normal	3.55	.38	2.53
		Chlorotic	3.56	.32	1.39
6	Kudzu and Merker grass + 50 lbs. borax	Normal	2.90	.31	2.16
		Chlorotic	2.86	.31	1.49
7	Kudzu + 300 lbs. K_2O	Normal	3.17	.43	3.42
		Chlorotic	—	—	—
8	Kudzu and Merker grass + 300 lbs. K_2O	Normal	3.20	.31	2.60
		Chlorotic	—	—	—

[1] All treatments received 50 lb. of N and 100 lb. P_2O_5 per acre.

[2] A normal leaf is one having no visual symptoms of any nutritional deficiency; a chlorotic leaf is one which showed yellowing with the veins remaining green, burning of the edges, and necrotic spots.

Merker grass on the potash-treated plots. The kudzu showed no consistent increase in potassium content when potash was applied.

There were chlorotic kudzu plants in all plots which did not receive potash applications. The symptoms of chlorosis were similar to those seen on the previous kudzu-Merker grass associations and consisted of a yellowing of the older leaves and a burning of the margins of the leaves. The chlorosis was present both in kudzu growing alone and kudzu growing with

Merker grass (see fig. 1). The degree of chlorosis was more severe for the second cutting than for the first. The rainfall was less for the second than for the first cutting, and the chlorosis was at its height during the drier period.

Samples were taken of chlorotic and normal kudzu leaves from the various plots 2 weeks prior to harvesting the second cutting. The results of the chemical analyses of these are given in table 3. Chlorotic leaves were found in abundance in all plots except those receiving potash applications (treatments 7 and 8, table 3). The outstanding difference in the chemical analyses of the normal and chlorotic leaves was the lower potassium values of the latter. The average potassium content of the normal leaves was 2.56 percent while that of those from chlorotic kudzu was 1.44, a reduction of 44 percent. The potassium in the harvested kudzu (table 2) was higher than the values given for the chlorotic leaves (table 3), even though these plots received no potash. However, the values in table 2 represented total kudzu harvested including vines and leaves, whereas, the values in table 3 were for kudzu leaves only.

The chemical analyses of leaves representing the magnesium oxide and boron treatments failed to show any appreciable differences in either tables 2 or 3. Work performed by the authors using white beans as an indicator crop in a greenhouse experiment disclosed no response to magnesium applications for Fajardo clay. Bonnet (2) found these soils to have 180 p.p.m. available magnesium and 849 p.p.m. available calcium.

DISCUSSION

Competition for nutrients in grass-legume associations has been reported by many workers. Blaser and Brady (1) found competition for potassium in grass-legume mixtures in New York State. They were of the opinion that competition might result in legumes being retarded or eliminated on soils containing insufficient available potassium. If maintenance of the legume is a primary objective, potash should be adequately supplied to mixed stands of grasses and legumes.

Warmke, Freyre, and García (7), working with tropical grass-legume associations in Puerto Rico, encountered similar competition for potassium between grass and legume. They obtained a 38-percent decrease of potassium in kudzu grown in association with Merker grass as compared with kudzu growing alone.

Parsons, *et al.* (6) stated that competition for potassium between desirable forage species and undesirable weedy species had a pronounced influence on the longevity of the stand. After 3 crop years, they found that Ladino clover comprised less than 5 percent of the vegetation on low-potash plots which originally grew pure stands of Ladino clover. The remaining vegeta-

tion was predominantly the weedy grasses, Kentucky bluegrass, and bentgrass.

It appears that grass wins out in the competition for potassium between grass and legume growing in association. The grass will obtain potassium first from the available soil supply and the legume must take the remainder. If the total supply of available potash in the soil is high, then neither plant species suffers. However, if the grass-legume association is planted on soils containing sufficient supplies of potash for only one of the crops, they will show a deficiency of potassium. It appears that insufficient supplies of soil potash are available in Fajardo clay to support a kudzu-Merker grass association in a healthy condition. The supply of available soil potash becomes even lower during the drier weather encountered in part of the growing season. This fixation of potassium in the soil by drying has been demonstrated by Joffe and Kolodny (3).

Consideration should be given to the available potash supply in the soil when growing grass-legume associations in Puerto Rico. This is especially true if continued good stands of the legume are to be obtained in a mixed grass-legume stand.

SUMMARY

Examination of a competition for potassium in a kudzu-Merker grass association on Fajardo clay at Río Piedras showed:

There were no significant responses in yields to the application of potash, magnesium oxide, or borax by either kudzu or a kudzu-Merker grass mixture for two cuttings.

The highest gain in yield was obtained when potash was applied to the kudzu-Merker grass association.

A chlorosis of the kudzu evidenced by a yellowing of the older leaves with marginal leaf-burning was found on all plots not receiving potash. This chlorosis was more severe during the drier weather than in the rainy season.

Leaf analysis of the kudzu and Merker grass at harvesttime revealed no appreciable difference in protein, nitrogen, or phosphorus contents attributable to any of the treatments.

Potassium values were all lower for the kudzu grown with Merker grass than for that grown alone.

Samples of chlorotic kudzu leaves taken before harvest contained less potassium than normal kudzu leaves taken from the same plots.

Evidence is presented of the competition for potassium by grasses and legumes as was found by other workers. The authors also discuss the importance of this competition in establishing legumes in grass-legume mixtures for soils low in available potash in Puerto Rico.

RESUMEN

Las investigaciones relacionadas con la competencia entre el kudzu y la yerba Merker por el potasio, cuando se desarrollaron asociadas en una arcilla Fajardo en Río Piedras, demostraron lo siguiente:

Las aplicaciones de potasio, óxido de magnesio, y borax no afectaron los rendimientos del kudzu ni los de la asociación kudzu-yerba Merker, cuando se cortaron dos veces sucesivamente.

Los mayores aumentos en los rendimientos se obtuvieron cuando se aplicó potasio a la asociación kudzu-yerba Merker.

En todas las parcelas que no recibieron aplicaciones de potasio, se observó clorosis en el kudzu, la cual estuvo caracterizada por una amarillez de las hojas más viejas. Estas aparentemente desarrollaron lesiones, como quemaduras, a lo largo de las márgenes. El estado clorótico se manifestó con mayor intensidad durante las épocas de sequía y con menor durante las de lluvia.

Los análisis foliares de las muestras del kudzu y de la yerba Merker, tomadas simultáneamente durante el corte, señalaron diferencias importantes en el contenido de proteína, nitrógeno y fósforo que bien podrían atribuírsele a los tratamientos.

El kudzu en asociación con la yerba Merker tuvo, en todos los casos, un contenido más bajo de potasio que el que creció solo.

Los análisis de las muestras de hojas cloróticas de kudzu recogidas antes del corte, tuvieron un contenido menor de potasio que los de las hojas no cloróticas o normales obtenidas de la misma parcela.

En este trabajo se presentó evidencia conseguida por varios investigadores relacionada con la competencia entre yerbas y leguminosas por el potasio. Los autores discuten también la importancia de dicha competencia para el desarrollo de las leguminosas en asociación con las yerbas en aquellos suelos que contengan poco potasio asimilable.

LITERATURE CITED

1. Blaser and Brady, Nutrient competition in plant associations, *Agron. J.* **42** 128–35 1950.
2. Bonnet, J. A., Riera, A. R., Rivera-Brenes, L., and Orlandi, R., Tracing the mineral from the soil to the plant to the animal blood: I, Effect of lime on the mineral composition of the soil, of the grass, and on the crop yield, *J. Agr. Univ. P. R.*, **30** 138–58 1946.
3. Joffe, J. S. and Kolodny, L., The effect of alternate wetting and drying on the base exchange complex with special reference to the behavior of the K-ion, *Soil Sci. Soc. Proc.* 1938, **3** 107–11, 1939.
4. Kitchen, H. E., Diagnostic techniques for soils and crops, The American Potash Institute, Washington, D. C., 1948.
5. Landrau, P. Jr., Samuels, G., and Rodríguez, J. P., Influence of fertilizers, minor

elements, and soil pH, on the growth and protein content of tropical kudzu, *J. Agr. Univ. P. R.* **37** 81–95 1953.

6. Parsons, J. L., Drake, M., and Colby, W. G., Yield and vegetative and chemical composition of forage crops as affected by soil treatment, *Soil Sci. Soc. Proc.*, **17** (1) 42–5 1953.
7. Warmke, H. E., Freyre, R. H., and García, J., Evaluation of some tropical grass-legume associations, *Trop. Agr.* **29** (4–6) 115–21 1952.

RESULTS OF TESTS WITH NEW FUNGICIDES FOR THE CONTROL OF DAMPING-OFF OF TOBACCO IN PUERTO RICO

L. A. Alvarez-García and Lidy López-Matos[1]

INTRODUCTION

Damping-off of tobacco seedlings continues to be a serious problem in Puerto Rico, particularly in periods of frequent rainfall. Results of previous work by the Plant Pathology Department have shown that damping-off can be controlled by weekly sprayings with Bordeaux Mixture (4-4-50). Formaldehyde and steam sterilization though effective to a certain extent, are not considered economically practical in our agricultural environment.

The importance of spraying for successful production of tobaco seedlings has been demonstrated time and again. The discovery and synthesis of new chemicals for disease control suggested that they be tested for damping-off.

EXPERIMENTS IN 1950–51

At Aibonito

During the 1950–51 season an experiment was made at the Tobacco Seed Farm in Aibonito. The soil type of the experimental field is a Juncos clay with a pH of 5.5. The site used was a low round hill with a gentle slope. The experimental lay-out for this test was a randomized block design, including six treatments and a check; each treatment and check was replicated six times. The seedbed was prepared under cheesecloth. The seed were sown on October 9.

The following fungicidal chemicals were tested: Fermate (65 percent Ferbam-ferric dimethyl dithiocarbamate); Dithane Z-78 (zinc ethylene bisdithiocarbamate); Parzate (zinc ethylene bisdithiocarbamate); Compound A (copper oxychloride); and Bordeaux Mixture (4-3-50). The carbamates were used at a rate of 2 pounds per 100 gallons of water. Water in equivalent amount was used for the checks.

The fungicidal suspensions were applied at rates of 1 and 1½ gallons per square yard, in the first and second weekly sprayings, respectively. In the third weekly spraying, and after, 2.5 gallons of fungicidal suspensions were applied per square yard. The treatments were discontinued after the seventh weekly spraying. The seedlings had then reached the transplanting stage.

The weather was favorable for damping-off development during the

[1] Plant Pathologist and Head of Department and Research Assistant in Plant Pathology, respectively, Agricultural Experiment Station, University of Puerto Rico, Río Piedras, P. R.

growing period. The frequent rainfall kept the soil completely saturated most of the time.

The results indicate the importance of chemical spraying for disease control and show the relative efficacy of the chemical compounds tested.

The percentages of infection in each treatment are presented in table 1.

The analysis of variance of the data collected shows that all treatments were significantly effective when compared with the check.

It should be mentioned that Bordeaux Mixture was slightly phytotoxic to very young plants, also that Fermate burned and caused about 10 percent

TABLE 1.—*Results of using chemical fungicides for damping-off control at Aibonito, autumn 1950*

Fungicide	Percentage of infection[1]
Bordeaux Mixture	1.98
Copper A Compound	2.50
Fermate	11.90
Dithane Z-78	18.55
Parzate	18.75
Check	88.48

[1] S. E. D. = 8.34
L. S. D. (including Check):
At 5-percent point = 8.34 (2.060) = 17.18
At 1-percent point = 8.34 (2.787) = 23.25
S. E. D. = 4.58
L. S. D. (excluding Check):
At 5-percent point = 4.58 (2.086) = 9.55
At 1-percent point = 4.58 (2.845) = 13.03

of damage to 1-week-old seedlings, accompanied by a marked retardation of their growth. This retarding effect could be advantageous during wet seasons by reducing the number of spindled seedlings.

Fermate was, however, less phytotoxic to seedlings that had attained about 2 inches in height. Some injured seedlings recovered and became dark-green, sturdy, though somewhat dwarfed plants.

From the analysis of variance (excluding the Check) it can be seen that at the 1-percent level, Bordeaux Mixture, Copper A Compound, and Fermate were equally effective and significantly superior to Dithane Z-78 and Parzate.

At the 5-percent level, Bordeaux Mixture and Copper A Compound proved better than Fermate, Dithane Z-78, and Parzate.

It should be mentioned that the commercial seedbed at the Aibonito Farm was lost at this time because of a 100-percent infection.

At San Lorenzo

The same design was used to test the chemicals at the San Lorenzo Seed Farm. The only difference in procedure was the application of 1 gallon of each suspension per square yard of seedbed. None of the chemicals was phytotoxic at the concentrations (2 pounds per 100 gallons) used for the

TABLE 2.—*Results of using chemical fungicides for damping-off control at San Lorenzo, autumn 1951*

Fungicide	Percentage of infection[1]
Copper A Compound	11.36
Bordeaux Mixture	14.85
Fermate 2-100	37.72
Fermate 1-100	39.39
Dithane Z-78	64.39
Check	70.60

[1] S. E. D. = 13.74
L. S. D.: At 5-percent point = 28.68
At 1-percent point = 39.12

TABLE 3.—*Results of using chemical fungicides for damping-off control at Caguas, 1951*

Fungicides	Percentage of infection[1]
Copper A Compound	15.00
Copper A Compound plus lime (half and half)	15.94
Bordeaux Mixture	16.51
Dithane Z-78	74.99
Fermate	85.60
Check	100.00

[1] S. E. D. = 7.979
L. S. D.: At 5-percent point = 16.64
At 1-percent point = 22.70

carbamates and at (4-3-50) for Bordeaux Mixture. The soil used for the seedbed was a Las Piedras sandy-clay loam with a clay subsoil. The pH of the topsoil was 5.8.

The percentages of infection per treatment are presented in table 2.

According to the analysis of variance all the treatments with the exception of Dithane Z-78 and Fermate were significantly superior to the Check at the 1-percent level. Copper A and Bordeaux Mixture were significantly superior to Dithane Z-78 at the 1-percent level. Fermate was superior to the Check at 5-percent level.

At Caguas

The same plot design was followed and the same treatments at the same rate and concentrations were used at Caguas. The soil used was a Caguas sandy-clay loam of pH 4.80.

The results of the experiment are presented in table 3.

According to this analysis Copper A Compound, Copper A Compound plus lime (powder treatment), and Bordeaux Mixture were significantly superior to Fermate, Dithane Z-78, and the Check at the 1-percent level. There was no significant difference between Copper A Compound spray, Copper A plus lime (half and half) and Bordeaux Mixture at the 5-percent and 1-percent levels.

Dithane Z-78 was significantly superior to Fermate at the 5-percent level. Dithane Z-78 was superior to the Check at the 1-percent level.

The rank of the fungicides in order of merit was: Copper A Compound, Copper A plus lime, Bordeaux Mixture, Dithane Z-78, and Fermate.

DISCUSSION AND CONCLUSIONS

Damping-off of tobacco cannot be absolutely erradicated in our soils but it can be controlled practically with chemical treatments. Copper in such forms as in Bordeaux Mixture and copper oxychloride was somewhat superior in keeping the infection at a minimum under most varying conditions of soil and climate.

The degree of efficacy of the various chemicals varies with the soil and the climatic environment at the time of the application. It is known that fungicidal chemicals differ in efficacy under varying agricultural conditions. This in part explains why there was less difference in efficacy at Aibonito and marked variation at San Lorenzo and Caguas.

On the basis of these tests in Aibonito, Caguas, and San Lorenzo it seems reasonable and practical to use any of the fungicides for control of the damping-off. However, it might be desirable under certain conditions to use two chemicals alternately. The retarding growth effect of Fermate could be advantageous during periods of frequent rainfall in order to avoid spindled growth. Spraying every other week with Copper A Compound and Fermate alternately would perhaps be very effective under such circumstances.

The use of chemicals in powder form (dusting) during wet periods is recommended because the use of sprays adds to the water content of the soil thus creating more favorable conditions for damping-off development.

The frequency of application must be considered. Mere weekly applications may be insufficient. Spraying or dusting should be practiced whenever necessary. During moderately wet periods spraying is acceptable, but dusting is preferable during very humid periods.

The phytotoxicity of the chemicals must be considered. Compound A is

less soluble than Bordeaux Mixture, therefore less phytotoxic, and can be applied with less risk during the early growth of the seedlings. Bordeaux and Fermate are a little toxic under hot, humid conditions but not to the extreme of killing the plants.

A field test with seedlings taken from each respective treatment showed that the early phytotoxic effect of Bordeaux Mixture and Fermate had very little or no effect on the yield of leaf tobacco.

SUMMARY

1. Experiments for the comparative testing of new fungicidal chemicals for the control of damping-off of tobacco were performed at Aibonito, Caguas, and San Lorenzo.

2. In Aibonito, Bordeaux Mixture and Copper A Compound proved superior to Fermate, Dithane Z-78, and Parzate.

3. In San Lorenzo, Bordeaux Mixture and Copper A Compound also proved superior to Fermate, Dithane Z-78, and Parzate.

4. In Caguas, Bordeaux Mixture and Copper A Compound again proved superior to Dithane Z-78 and to Fermate.

5. All treatments, however, were practically effective in controlling damping-off.

RESUMEN

Con el propósito de comparar la eficacia de varios nuevos fungicidas con el caldo bordelés, para combatir la micosis del pie (sancocho) en los semilleros de tabaco, se realizaron varios experimentos en Aibonito, San Lorenzo y Caguas. El resultado de la experimentación ha demostrado que todos los fungicidas probados son prácticamente eficaces y dominan el "sancocho" de los semilleros de tabaco.

No obstante, los mejores resultados, en términos generales, fueron los conseguidos con los compuestos de cobre.

FUNGICIDAL CONTROL OF EARLY AND LATE BLIGHT OF THE POTATO IN PUERTO RICO

L. A. Alvarez-García, J. Adsuar, J. P. Rodríguez, A. C. Miret, F. Arostegui, R. Olivencia, and F. Rochet[1]

INTRODUCTION

The control of early and late blight of potato is one of the important problems in the commercial production of potatoes in Puerto Rico. The diseases considerably reduce the yield and greatly affect the market value of the product.

Early and late blight of potatoes are endemic diseases in Puerto Rico and epiphytotics may occur at any time during the growing season from November to February. The weather at this time of the year is rather variable with occasional cool nights and warm days, frequent rains, and high relative humidity. Late blight is usually more serious in this environment.

It is generally known that late blight is a low-temperature disease. The temperature during the winter season fluctuates from 70° to 75° F. during daytime and from 60° to 65° F. at night. These conditions are favorable for development of late blight. Rainfall is not so important as long as there are cool nights and sufficient dew for swamspore germination and leaf penetration. Early blight is a hot humid-weather disease and temperatures above 70° F. favor its development. Such weather conditions occur in Puerto Rico during the potato-growing season.

Late blight of potatoes is considered a seedborne disease. In certain regions the seed piece is the source of the primary inoculum. Under our conditions the source of the primary inoculum does not necessarily depend on infected tubers, if we consider that tomato, eggplant, and other solanaceous plants grow spontaneously the year round.

The occurrence of epiphytotics of early and late blight in Puerto Rico therefore is primarily due to the endemism of the pathogens responsible for these diseases and to the generally favorable local environment. Puerto Rico is a small island, but there are many unsuspected microclimates, both in the lowlands and in the highlands, apparently adequate for the year-round existence of these micro-organisms.

The question of controlling early and late blight is of deep concern to the farmers and the public. Early and late blight have been kept under fairly

[1] Plant Pathologist and Head of Department, Plant Pathologist, Associate Agronomist, Research Assistant in Agronomy, Associate Agronomist, Assistant Plant Breeder, and Assistant Agronomist, respectively, Agricultural Experiment Station, University of Puerto Rico, Río Piedras, P. R.

good control by the use of the classical Bordeaux Mixture. The synthesis and discovery of new fungicidal chemicals has opened a new field of control measures. There are reports of effective control of early and late blight with some of these new chemicals. The order of merit of some of those chemicals, however, varies with the crops and the environment under which they are tested. Hence, it has been necessary to determine the efficacy of some of them in our local environment. This paper deals with the results obtained with some new fungicides (compared with the standard Bordeaux Mixture) in controlling early and late blight of potato.

MATERIALS AND METHODS

Unless otherwise stated, all the potatoes planted have been grown from certified seed tubers brought from the mainland. The seed were planted

TABLE 1.—*Active principles of fungicidal chemicals tested for their effect on potato yields in the experiments reported*

No.	Trade name	Active principle
1	Bordeaux Mixture	Basic copper sulfates
2	Copper A Compound	Copper oxychloride
3	Dithane D-14	Disodium ethylene bisdithiocarbamate
4	Dithane Z-78	Zinc ethylene bisdithiocarbamate
5	Parzate	Do.
6	Phygon XL	Dichloronaphtoquinone
7	Fermate	Ferric dimethyl dithiocarbamate
8	Zerlate	Zinc dimethyl dithiocarbamate

immediately after breaking dormancy. Previous to planting each was cut in pieces and sown 3 feet apart, in ridges, 15 inches in the row. The potatoes were grown without irrigation.

The fungicidal chemicals used in our tests (table 1) were in great majority solids insoluble in water. They entered readily into suspension because of the addition of wettable agents. In all instances the recommendations of the manufacturers were followed. The chemicals were sprayed the same day and immediately after being prepared. A Vermorell-type sprayer was used to apply the chemicals on both the upper and under surfaces of the leaves. Weekly sprayings were performed. Records of rainfall, relative humidity, and temperatures were taken whenever possible. Samples of leaves were examined every week to establish the degree of infection and the responsible organism.

Treated plants were grown in plots, in replicate, to permit statistical analysis. Records were taken of the appearance of the treated plants, injury of the leaves, type of growth, and yield and quality of produce. The plants

were sprayed with concentrated $CuSO_4$ solution before harvesting in order to kill the mycelia and spores of the pathogen in the soil and in the aerial parts of the plants. In this manner the possibility of contamination of the potato tubers at harvesting was eliminated.

To evaluate the fungicidal effects of the chemicals tested, the data were statistically analyzed.

EXPERIMENTAL RESULTS

Control of Early Blight

FIELD TRIAL NO. 1

A first trial was conducted at the Río Piedras Agricultural Experiment Station, in field A-1. This time the varieties Red Bliss Triumph and Irish Cobbler were grown. The seed were sown December 29, 1948. The plantation was fertilized with a 10-10-5 fertilizer, at a rate of 1,200 pounds per acre. The fungicides tested were Parzate, Zerlate, Dithane Z-78, Copper A Compound, and Bordeaux Mixture. The treatments were randomized and replicated nine times in plots of $\frac{1}{200}$ of an acre. During this late planting, the weather was unfavorable for development of early blight. The temperature was around 27° C. and there was a dry spell, but there was sufficient water of condensation during the night to permit spore germination and penetration. Irrigation water was used whenever necessary to permit good growth of the plants. The merit of each treatment is shown in table 2.

FIELD TRIAL NO. 2

A second trial with Red Bliss Triumph potato was conducted at Cidra. A 10-10-5 fertilizer was applied at the rate of 1,500 pounds per acre. The seed were sown February 2, 1949, and the potatoes were harvested May 12, 1949. They were grown in randomized plots of $\frac{1}{100}$ of an acre. The treatments were replicated six times following a paired-plot system. The fungicides tested were Parzate, Zerlate, Phygon XL, Dithane Z-78, Copper A Compound, and Bordeaux Mixture. The experiment was carried on in a field on the T. Fernández Farm, Bo. Bayamón, Cidra. Rainfall during the growing season was approximately 7 inches. Watering was sometimes necessary.

The plants were sprayed with the chemicals following the method indicated previously. During the growing period the potatoes suffered a mild attack of *Alternaria* blight. The results of this experiment are shown in table 3.

FIELD TRIAL NO. 3

Another trial was conducted with Red Bliss Triumph potato at the Corozal Substation. The seed were sown in February 1950 and the crop was

TABLE 2.—*Results of fungicidal treatments to control early blight* (Alternaria solani) *in the varieties Red Bliss Triumph and Irish Cobbler potatoes during the planting season Dec. 29—Apr. 8, 1949*

[Field trial No. 1]

Fungicide used	Mean yield of potatoes per acre for—	
	Red Bliss Triumph[1]	Irish Cobbler[2]
	Cwt.	*Cwt.*
Zerlate	42.60	59.60
Copper A Compound	41.20	50.60
Dithane Z-78	39.60	58.60
Parzate	38.20	55.80
Bordeaux Mixture	35.40	44.00
Check	37.40	57.80

[1] L. S. D. at the 5-percent level = 3.860; at the 1-percent level = 5.165. Zerlate was superior at the 5-percent level when compared with Parzate, Copper A Compound, Bordeaux Mixture, and Check. At the 1-percent level Zerlate proved better than Copper A Compound, Bordeaux Mixture, and Check.

[2] L. S. D. at the 5-percent level = 4.709; at the 1-percent level = 6.300. Zerlate, Dithane Z-78, Parzate, and Copper A Compound were significantly superior at the 1-percent level when compared with Bordeaux Mixture, but not when compared with the Check. Zerlate proved better than Parzate at the 5-percent level and better than Copper A Compound and Bordeaux Mixture at the 1-percent level.

TABLE 3.—*Results of fungicidal treatments to control early blight* (Alternaria solani) *in the Red Bliss Triumph potato grown at Cidra during the planting season Feb. 2—May 12, 1949*

[Field trial No. 2]

Fungicide used	Mean yield of potatoes per acre, by size		
	Large[1]	Small[2]	Large and small[3]
	Cwt.	*Cwt.*	*Cwt.*
Parzate	71.80	17.0	88.50
Zerlate	79.70	14.8	94.50
Phygon XL	67.30	14.3	81.20
Dithane Z-78	71.70	14.2	90.50
Copper A Compound	68.20	13.8	81.50
Bordeaux Mixture	68.20	15.5	81.50
Check	60.5	15.3	75.70

[1] L. S. D. at the 5-percent level = 10.50; at the 1-percent level = 14.14.

[2] For plants yielding large potatoes Parzate, Zerlate, Phygon XL, Dithane Z-78, and Copper A Compound were better than the Check at the 5-percent level; Zerlate was better than Phygon XL or Bordeaux Mixture at the 5-percent level, and than the Check at the 1-percent level.

[3] For plants yielding large and small potatoes together Zerlate was better than Phygon XL or Bordeaux Mixture at the 5-percent level and better than the Check at the 1-percent level, while Parzate and Dithane Z-78 were better than the Check at the 5-percent level. The fungicides rated in the following order of merit: Zerlate, Dithane Z-78, and Parzate.

harvested on May 12, 1950. The potato seed used were kept in cool storage (50–60° F.) to planting time.

The period was dry and the potatoes were watered twice during the growing season. The plants were seriously attacked with early blight, caused by *Alternaria solani*. Insects were controlled with DDT and nicotine sulfate.

The potatoes harvested were classified into large and small. The results are shown in table 4.

TABLE 4.—*Results of fungicidal treatments to control early blight* (Alternaria solani) *in the Red Bliss Triumph potato grown at the Corozal Substation during the planting season February 8—May 12, 1950*

[Field trial No. 3]

Fungicide used	Mean yield of potatoes per acre, by size	
	Large and small[1]	Large[2]
	Cwt.	*Cwt.*
Check (No DDT or nicotine sulfate)	34.83	23.17
Parzate	51.33	38.67
Zerlate	47.35	35.67
Dithane Z-78	49.50	36.17
Phygon XL	40.33	29.19
Bordeaux Mixture	46.00	33.17
Check (DDT plus nicotine sulfate)	38.66	28.33

[1] L. S. D. at the 5-percent level = 3.06; at the 1-percent level = 4.13. Parzate proved better than the Check without, and the Check with DDT plus nicotine, Phygon XL, and Bordeaux Mixture at the 1-percent level. Dithane Z-78 was better than the Check with DDT plus nicotine, and Phygon XL at the 1-percent level, and than Bordeaux Mixture at the 5-percent level.

[2] L. S. D. at the 5-percent level = 2.57; at the 1-percent level = 3.35. Parzate proved superior at the 1-percent level to Zerlate, Phygon XL, Bordeaux Mixture, and the Check without DDT plus nicotine. Dithane Z-78 proved better than Phygon XL, and both Checks at the 1-percent level, and than Bordeaux Mixture at the 5-percent level.

Early blight (*Alternaria solani*) was prevalent during the growing season. The results were different from those obtained in the previous year when Zerlate was the best fungicide and Dithane Z-78 second. This year Parzate was the best fungicide and Dithane Z-78 second best for early blight control. Although the result was not statistically significant, Zerlate was very nearly as good as Parzate.

Control of Late Blight

FIELD TRIAL NO. 4

A fourth experiment was conducted at Stubb's Farm, Bo. Bayamón, Cidra, with the potato variety Katahdin. The field was fertilized with 1,500

pounds of a 10-10-5 fertilizer, applied before planting. The planting was made January 24, 1945. The potatoes were harvested on May 25 and 26, 1945. Bordeaux Mixture and Dithane D-14 were compared. The statistical analysis of the results is shown in table 5.

FIELD TRIAL NO. 5

A fifth experiment was conducted at the Corozal Substation. Red Bliss Triumph potatoes were sown in September 1950, and the crop was harvested during December 1950. Early during the growing season the temperature was around 80° F. Light scattered rainfall occurred at the beginning of the growing season. However, abundant fainfall, approximately 16 inches, was concurrent with the appearance of early blight. During the middle of the

TABLE 5.—*Results of fungicidal treatments to control late blight* (Phytophthora infestants) *of Katahdin potatoes grown at Cidra in the planting season Jan. 24—May 25, 1945*

[Field trial No. 4]

Fungicide used	Mean yield of potatoes per acre[1]
	Cwt.
Dithane D-14	47.92
Bordeaux Mixture	48.27
Check	41.10

[1] L. S. D. at the 5-percent level = 2.75; at the 1-percent level = 3.64. No significant differences between Dithane D-14, and Bordeaux Mixture. Dithane D-14, and Bordeaux Mixture were better than the Check at the 1-percent level.

growing season the temperature dropped to 70°F. and the relative humidity was high. It thus favored the development of late blight. The plants were grown in plots of $\frac{1}{108.9}$ of an acre, the treatments were replicated 5 times, and the number of plants per plot was 200. An incomplete block system was used consisting of 16 treatments of 4 groups of 4 plots in each plot. The fungicides tested were Bordeaux Mixture, Copper A Compound, Zerlate, Dithane Z-78, Parzate, and Phygon. The results of these treatments are shown in table 6.

FIELD TRIAL NO. 6

The same method of planting and spraying used for the previous experiments was followed in Field Trial No. 6. The planting was to have been made simultaneously with the same variety used in Trial No. 4, but because it proved impossible to obtain fresh seed from the mainland at that time, it had to be postponed until January 1951, when the field in Corozal was sown with Red Bliss Triumph potatoes. The crop was harvested on March

TABLE 6.—*Results of fungicidal treatments to control late blight* (Phytophthora infestans) *in Red Bliss Triumph potatoes grown at the Corozal Substation during the planting season Sept. 9—January 1950*

[Field Trial No. 5]

Fungicide used	Mean yield of potatoes per acre, large and small[1]
	Cwt.
Copper A Compound	82.76
Bordeaux Mixture	73.83
Dithane Z-78	72.31
Parzate	54.23
Check No. 1 (DDT plus nicotine sulfate)	48.35
Zerlate	42.04
Phygon XL	34.85
Check No. 2 (no DDT or nicotine sulfate)	33.76

[1] L. S. D. at the 1-percent level = 22.05; at the 5-percent level = 16.7. Copper A Compound, Bordeaux Mixture, and Dithane Z-78 proved better than Parzate, Zerlate, Phygon XL, and the two Checks at the 1-percent level. At the 5-percent level, Parzate proved better than Phygon XL, and Check No. 1.

TABLE 7.—*Results of fungicidal treatments to control late blight* (Phytophthora infestans) *of Red Bliss Triumph potatoes grown at the Corozal Substation during the planting season January—March 1951*

[Field Trial No. 6]

Fungicide used	Mean yield of potatoes per acre, by size	
	Large[1]	Large and small[2]
	Cwt.	*Cwt.*
Bordeaux Mixture	45.13	67.36
Copper A Compound	42.51	62.57
Phygon XL	38.80	60.39
Dithane Z-78	37.06	57.99
Parzate	34.23	55.59
Zerlate	32.70	50.14
Check No. 1, (DDT plus nicotine sulfate)	26.16	47.31
Check No. 2, (no DDT or nicotine sulfate)	23.32	46.87

[1] There was no significant difference at the 1-percent level among the chemical treatments and all these treatments were superior to the Check with no insecticides. At the 5-percent level all these chemical treatments were better than both Checks.

[2] L. S. D. at the 1-percent level = 21.11; at the 5-percent level = 15.64. There was no significant difference among the treatments at the 1-percent level. At the 5-percent level, Bordeaux Mixture, Copper A Compound, Phygon XL, Dithane Z-78, and Parzate were superior to Zerlate, and both the Checks.

19, 1951. Phygon-treated plants looked yellowish but had only a low degree of infection.

It can be seen in table 7 that the yield was less than that obtained previously. However, during this period a dry spell lowered the yield. Though the yield was less, the potatoes were larger, better shaped, and of better quality. No decay has been observed so far. Results are shown in table 7.

CONCLUSIONS

Results of tests made with new fungicides at Río Piedras, Cidra, and Corozal have shown that these chemicals can control early and late blight of potatoes.

The efficacy of the fungicides varied with the environmental conditions and also with the type of blight. The use of chemical treatments substantially increased the yield of potatoes per acre.

During very adverse seasons when rainfall was scanty or too abundant, the yield was rather low, even though the plants were sprayed. Spraying increased production during so-called normal years.

Potato culture—on a limited scale—would be less risky if potato varieties with at least 1-gene resistance to the common race of *P. infestans* are grown. Better results are to be expected in the future when new 3-gene-resistant varieties, with good adaptation to short-day periods of growth are released.

SUMMARY

Experiments were conducted at Río Piedras, Cidra, and Corozal to determine the relative efficacy of certain newer fungicides for control of early and late blight of potatoes.

The data derived from the various experiments may be summarized as follows for early blight control:

1. At Río Piedras, December–April 1949, Zerlate was superior at the 5-percent level to Parzate, Copper A Compound, and Bordeaux Mixture for the control of early blight. At the 1-percent level, Zerlate proved better than Copper A Compound or Bordeaux Mixture.
2 At Cidra, February–May 1949, Zerlate was better than Phygon XL or Bordeaux Mixture at the 5-percent level for control of early blight. Parzate and Dithane Z-78 were better than the Check at the 5-percent level.
3. At Corozal, February–May 1949, Parzate proved superior to Zerlate, Phygon XL, Bordeaux Mixture, and the Check at the 1-percent level. Dithane Z-78 was better than Phygon XL and both Checks at the

1-percent level, and superior to Bordeaux Mixture at the 5-percent level.

For late blight control:

1. At Cidra, January–May 1945, Dithane D-14 was equal to Bordeaux Mixture and superior to the Check for the control of late blight.
2. At Corozal, September–December 1950, Copper A Compound, Bordeaux Mixture, and Dithane Z-78 proved superior to Parzate, Zerlate, Phygon XL, and the Check at the 1-percent level. At the 5-percent level Parzate proved better than Phygon XL and Check No. 1.
3. At Corozal, January–March 1951, a second experiment showed that Copper A Compound, Bordeaux Mixture, Dithane Z-78, Parzate, Phygon XL, and Zerlate were equally superior to the Check at the 1-percent level. At the 5-percent level Bordeaux Mixture, Copper A Compound, Phygon XL, Dithane Z-78, and Parzate were superior to Zerlate and to the Checks.

RESUMEN

En este trabajo se presentan datos en relación con la eficacia de los nuevos fungicidas para combatir el tizón tempranero (*Alternaria solani*) y el tizón tardío (*Phytophthora infestans*) respectivamente, que atacan a las papas (*Solanum tuberosum*) en Puerto Rico.

Los resultados de los experimentos para combatir el tizón tempranero fueron:

1. En Río Piedras, durante el período de cultivo de la variedad Red Bliss, desde diciembre 29 a abril 8, 1949, el Zerlato en términos estadísticos del 5 por ciento[2] fué superior al Parzato, al Compuesto A de cobre, al Caldo Bordelés y al testigo. Y al 1 por ciento, el Zerlato fué superior al Compuesto A de cobre, al Caldo Bordelés y al testigo.

En las papas de la variedad Irish Cobbler, el Zerlato, el Ditano Z-78, el Parzato y el Compuesto A de cobre fueron superiores al Caldo Bordelés al 1 por ciento, pero no así cuando se compararon con el testigo. El Zerlato, al 5 por ciento, fué superior al Parzato, y al 1 por ciento, también superior al Compuesto A de cobre y al Caldo Bordelés.

2. En Cidra, durante el período de cultivo, desde febrero a mayo de 1949, cuando se usó la variedad Red Bliss Triumph, el Zerlato fué superior al Phygon XL, y al Caldo Bordelés al 5 por ciento y mejor que el testigo, al 1 por ciento. El Ditano Z-78 y el Parzato fueron superiores al testigo, al 5 por ciento.

3. En Corozal, con la variedad Red Bliss Triumph, durante el período de febrero 8 a mayo 12 del 1950, el Parzato fué superior al Zerlato, al

[2] Cuando se mencionan el 1 y el 5 por ciento éstos se refieren a los por cientos estadísticos, según el análisis estadístico de Fisher.

Phygon XL, al Caldo Bordelés y al testigo, sin insecticidas, al 1 por ciento. Al 1 por ciento, el Ditano Z-78, fué superior al Phygon XL y también superior a los dos testigos y al Caldo Bordelés, al 5 por ciento.

En Cuanto al tizón tardío:

1. En Cidra, durante el período de cultivo de enero 24 a mayo 25, 1945, con la variedad Katahdin, el Dithano Z-78 y el Caldo Bordelés fueron igualmente superiores al testigo, al 1 por ciento.

2. En Corozal, de septiembre a diciembre del 1950, el Compuesto A de cobre, el Caldo Bordelés y el Ditano Z-78 fueron superiores al Parzato, al Phygon XL y a los dos testigos, al 1 por ciento. Al 5 por ciento, el Parzato fué superior al Phygon XL y al testigo número 1.

3. En Corozal, de enero a marzo 19 del 1951, los fungicidas: Caldo Bordelés, Compuesto A de Cobre, Phygon XL, Ditano Z-78, Parzato y Zerlato no demostraron ser superiores a los testigos; porque la enfermedad no tuvo importancia. Al 5 por ciento, se notó que hubo una pequeña superioridad del Caldo Bordelés, el Compuesto A de cobre, el Phygon XL, el Ditano Z-78 y el Parzato sobre el Zerlato y los testigos 1 y 2.

REFERENCES CONSULTED

1. Black, William, Blight in relation to potato breeding, *Ann. Appl. Biol.* **34** 631-3 1947.
2. Crosier, Willard, Studies on the biology of *Phytophthora infestans* (Mont.) de Bary, Cornell Agr. Expt. Sta. Memoir **155**, 1934.
3. Jones, L. R., Giddings, N. J., and Lutman, B. F., Investigations of the potato fungus *Phytophthora infestans*, U. S. Dept. Agr. Bul. **245**, 100pp., 1912. (Also published as Vt. Agr. Expt. Sta. Bul. **168**).
4. Melhus, I. E., Hibernation of *Phytophthora infestans* in the Irish potato, *J. Agr. Res.* **5** 71-102 1915.
5. ——, Germination and infection with the fungus of the late blight of potato (*Phytophthora infestans*), Wis. Agr. Expt. Sta. Res. Bul. **37**, 64pp., 1915.
6. Mills, W. R., The National Potato-Breeding Program twentieth Annual Report to Cooperators, 153-4 pp., mimeographed U. S. Dept. Agr. 180pp., 1949.
7. Reddrick, Donald, and William Crosier, Biological specialization in *Phytophthora infestans*, *Am. Pot. J.* **10** 129-34 1933.
8. ——, Development of blight-immune varieties, *Amer. Pot. J.* **20** 118-26 1943.
9. U. S. Dept. Agr., the Plant Disease Reporter National-wide results with fungicides in 1947—51, Supplements 176, 181, 192, and 213, 1948-51.